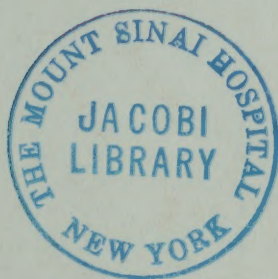




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**INDUSTRIAL POISONS IN
THE UNITED STATES**



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INDUSTRIAL POISONS IN THE UNITED STATES

BY

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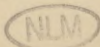
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PREFACE

THE sources of our knowledge of industrial poisoning in the United States are neither full nor, for the most part, accurate. We lack the sickness insurance system which obtains in all industrial countries in Europe and which brings to light the incidence of illness of all kinds in all groups of workers. Nothing takes its place in this country. Our private insurance companies sometimes gather important and trustworthy data, but these are never all-inclusive and never can be, they are always restricted to the group of individuals insured in that company. The Census reports are of deaths only, not illness, and the death records lose much of their value because of a poor classification of workers, which puts into the same category men doing work of very different degrees of danger, as for instance paper-hangers and painters. Trades union records are seldom of value, with the exception of those gathered by the typographical unions which were reviewed carefully by Verrill* and found to contain much that was interesting to the statistician.

It has been my task for many years to examine records of hospitals and dispensaries and to interview physicians in many parts of the country in my search for information about a given poisonous trade. Not one hospital in twenty has records which yield the sort of information which the student of industrial toxicology craves and yet this is not elaborate. If the recording interne would only treat the poison from which the man is suffering with as much interest as he gives to the coffee the patient has drunk and the tobacco he has smoked, if he would ask as carefully about the length of time he was exposed to the poison as about the age at which he had measles, the task of the searcher for the truth about industrial poisons would be made so very much easier. I have often had to reject fully one-third of the cases of plumbism which have been treated in a hospital because the interne had no curiosity about the source of the lead, contented himself with the notation, "lead worker," and so made it impossible for me to know from which of the many lead trades the man came.

Physicians in private practice have given me the greatest assistance, yet there are limitations to the value of the information obtained in this way. The diagnosis must be accepted, of course, as the Bureau of the Census accepts the death certificates of all

* *Hygiene of the Printers' Trade*. A. Hamilton and C. N. Verrill. Bull. 219, Bureau of Labor Statistics, Washington. 1916.

physicians, but mental reservations may have to be made. One must always remember in a study of this kind the existence of a prejudice which may cloud the mentality of some first-class men. Apparently it is impossible for some physicians to treat industrial diseases with the detachment and impartiality with which they approach those diseases which are not confined to the working classes. For a striking example of this the reader is referred to a bulletin issued by the Bureau of Labor Statistics on a trade disease—not an intoxication—in stonecutters.* The evidence is given from a doctor who worked for the stonecutters' union and from two who were brought in by the employers. Not only is there the widest divergence of views presented, but the physician who was retained by the men shows so strong a sympathy for them as to quite dull his critical sense, and the physicians for the companies accept evidence which is on the face of it one-sided, and then indulge in moral observations on the character of workmen and the evils of trades-unionism.

Another drawback to the obtaining of information from physicians is the fact that, since the passage of workmen's compensation laws, almost every plant in which poisons are handled now has its own physician and he is often unwilling to give out facts which may seem damaging to the company. On the other hand I have often had all the records laid frankly before me and been permitted to make what use I pleased of them.

No source of information should be despised. Apothecaries, visiting nurses, undertakers, charity workers, priests, often let drop valuable leads. The statements of the men themselves should be treated with respect, and checked up, and often they will prove to be founded on close observation. For instance, down in the copper region of Arizona I was told of cases of profound anemia and loss of strength among men engaged in the electrolytic production of copper, and when an examination of the premises showed no ground for this I was inclined to reject the tales, but closer study showed that in connection with this method there is always the possibility of arseniuretted hydrogen poisoning, if the copper carries some arsenic as it often does, and slow poisoning from this gas would bring about just such a condition as that described. The statement of some men in a white lead plant, that there was a good deal of plumbism among the men who made the blue bed, seemed to me exaggerated, because such men handle only clean lead buckles, but when I investigated I found that remnants of old corrosions were mixed with the latter, scraps covered with dusty white lead, and this was enough to account for the cases.

European literature is of enormous value for the physiological effects of a given poison and the mode of entrance, but it can tell us

* *Effect of the Air Hammer on the Hands of Stone Cutters.* U. S. Bureau of Labor Statistics. Bull. 236, 1918-19.

nothing about the probable incidence of poisoning in American industry because our methods differ decidedly from the European. Some trades which are dangerous there are quite harmless here. For instance, the making of cheap kitchen ware is one of the bad lead trades of England, here it is not a lead trade. Dyeing cotton and wool and handling them after dyeing, making files, polishing diamonds, these are occupations notoriously fraught with danger of lead poisoning in Europe, but not in the United States. On the other hand we have industries which are much more dangerous than theirs, such as the making of white lead by a dry process instead of a wet one, the use of large quantities of non-fritted white lead in pottery glazing, and the use of lead-laden enamel powder for sanitary iron ware. It is not possible to draw conclusions as to the danger of any occupation in the United States by simply consulting the foreign literature about it.

There has been an enormous increase in the interest of the medical world in industrial toxicology of late years, especially since our entrance into the war in 1917. There are already some studies of poisonous trades in the United States which for thoroughness leave nothing to be desired. Perhaps the study made by Edsall, Wilbur and Drinker * on manganese poisoning stands at the head of these, for they were able to study the incidence in a large group of workmen, the conditions under which poisoning occurred, the mode of entrance, and the clinical manifestations, of early stages of poisoning as well as of the later stages. At the foot would stand the single observation made by a physician in private practice on a case occurring in a plant to which he has no access and the description of which he must take from his patient. He cannot check up his findings, he cannot be certain that this, to him new and unfamiliar poison, is really responsible for the lesions he has observed; all he can do is to present his findings, suggest their possible significance and let it go at that. But he is really performing a valuable service when he does this, for such reports, incomplete as they must be, have often led to the exploration of a new and important field of industrial toxicology.

I have called this a study of industrial poisoning in the United States and have tried so far as possible to present American material, but obviously that is not always practicable and much that we owe to foreign observers has had to be included. It has been my purpose to avoid when I could the earlier writings which have been reviewed in the existing textbooks and to give as much new material as possible. The literature up to January 1, 1924, has been included.

* Edsall, D. L., Wilbur, F. P., and Drinker, C. K. *The Occurrence, Cause and Prevention of Chronic Manganese Poisoning. Jour. Indust. Hyg.*, 1919-20, I, 183.



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INDUSTRIAL POISONS IN
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INDUSTRIAL POISONS IN THE UNITED STATES

CHAPTER 1

INTRODUCTION TO INDUSTRIAL TOXICOLOGY

Chronic, Not Acute.—Industrial poisoning is typically chronic, the acute forms are relatively rare, although this is not as yet so true of industrial poisoning in the United States as it is in most European countries. Protection of workers in the dangerous trades in America is still fragmentary and incomplete and it is still true that men may be exposed to much more massive doses of a trade poison than is permitted in the older countries. We have in the United States a larger proportion of acute cases of poisoning from lead, benzene, anilin, petroleum distillates and methyl alcohol than occur in Great Britain, Germany or Holland. But even here the chronic cases, though less spectacular, are much more numerous and usually more serious than the acute. A man may die of acute benzene poisoning, but if he survives the heavy dose he recovers completely. Chronic benzene poisoning means aplastic anemia with purpura hemorrhagica, and if the man survives that, it is impossible for us to say, in our present state of knowledge, that he can completely recover normal health. The danger done by repeated small doses of lead is lasting, that done by one short exposure to heavily contaminated air is probably transient and leaves no permanent damage.

Mixed Poisons.—The diagnosis of industrial poisoning is likely to be rendered more difficult by the fact that the worker is so often exposed to more than one poison and the clinical picture is not clear-cut and typical. In zinc smelting the fumes contain zinc oxid, cadmium, lead and arsenic. Printers and rubber compounders come in contact with antimony as well as lead, but it is impossible to say how much of a rôle the former plays in the illness that ensues. Painters breathe fumes of benzene, wood alcohol, petroleum ether, amyl acetate, and still other volatile solvents. Makers of surgeons' rubber gloves breathe benzene and carbon disulphid. As for workers in coal tar dye manufacture and in the chemical trades, there is a bewildering number of toxic substances with which they may

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come in contact. A man engaged in producing the color auramin runs the risk of poisoning not only from a number of coal tar intermediates but from ammonia gas and sulphuretted hydrogen as well.

It is not enough to know what substances the patient has met with in his work, one must know also what sort of work goes on in his neighborhood. I have known two rubber workers who did not handle lead at all, but who acquired plumbism from the dust that rose from a neighboring mixing mill, and the fact that the mill men were apparently unharmed by the litharge dust naturally obscured the situation. A man engaged in the nitration of benzene became severely poisoned by the fumes of dinitrobenzene from some cooling pans near by, and a girl labeling paint cans in a clean room became poisoned by white lead dust which sometimes blew in through a door from an open chaser for the mixing of white lead paint.

There are several important factors which influence the incidence of industrial poisoning to an extent not always appreciated, some of which concern the worker himself, others the conditions under which work is done.

Hot and Humid Air.—Heat accelerates chemical action, and therefore accelerates the action of poisons. Heat facilitates the absorption of those poisons that pass through the skin, for a hot atmosphere flushes the surface blood vessels and causes profuse sweating. During the war it was very evident that cases of trinitrotoluene poisoning increased regularly whenever the weather was hot and humid (1). In one very dirty and neglected shell-loading factory, where direct contact with trinitrotoluene was absolutely unavoidable, there were during six days of normal summer weather, with the thermometer between 68 and 88 degrees F., only four men who sought treatment for "TNT sickness," but during six days of heat above 90 degrees F., there were twenty, nor did this represent the full number of cases of sickness, for during that hot spell hardly more than a third of the force reported for work.

The same thing is found to be true in anilin dye manufacture. There is invariably much more trouble, not only with anilin but with other intermediates, such as dinitrobenzene, the nitranilins, the nitrochlorbenzenes, the phenylendiamins, etc., in hot, moist weather than in cool, dry weather. In the summer of 1916, when the manufacture of intermediates was still in an experimental stage in the United States, one factory which produced dinitrochlorbenzene for sulphur black was obliged to close down because the men were practically all suffering from a distressing trade eczema. The German factory inspection reports covering the war period (2) show the effect of heat in increasing the cases of poisoning from dinitrobenzene, so largely used in their high explosive shells. In one plant

the cases of "DNB" poisoning averaged only 2.3 per cent for the cool autumn months, but 30.8 per cent for the summer months. So striking was the effect of heat on the incidence of poisoning that Koelsch, who was in charge of the Bavarian factory inspection department, succeeded in inducing one factory to have all the DNB work done before ten in the morning and after three in the afternoon, using the early and late cool hours.

Long Hours.—Without entering into the controversy as to whether fatigue lowers the resistance to poisons, it is safe to assert that long hours of work increase industrial poisoning simply because they increase the actual dose of poison and also lessen the chance of completely eliminating one dose before another is taken. It is obvious that a man will absorb more poison in ten hours than in eight hours or in six and he can eliminate more in sixteen hours than in fourteen. Observations that were made on TNT workers during the war showed that when there was not enough time between the shifts of work for a man to eliminate the TNT he had absorbed, the amount would accumulate and on Friday larger quantities would be appearing in the urine than on Monday. Repeatedly it was found that the urine when tested for the so-called Webster reaction would give a negative result after a holiday, a positive result at the end of the first eight-hour shift, and a reaction of increasing intensity as the week went on. The value of a short working day, the danger of overtime work and of the seven-day week, was shown clearly by these observations. It was also found that while some men could eliminate over night what had been absorbed during the day and others could get rid of the week's accumulation during Sunday and start on Monday with the urine free from the reduction product of TNT, which is shown by the Webster reaction, there were others who required a longer time, and that true economy would dictate the granting of several days holiday from time to time for over-susceptible workmen, as was done in Great Britain toward the end of the war.

The combined effect of long hours and heat was seen in one of the TNT shell-loading plants in the summer of 1916. June of that year was cool, work was not rushed, and during that month shell loaders worked only eight hours, then came a rush order with overtime, the men working ten, eleven, and twelve hours, even sixteen hours occasionally, for the high wages induced some to work two eight-hour shifts in twenty-four hours (3). This continued through the hot weather of July and August, the plant being situated down in Delaware in low, flat country. The cases of TNT poisoning during June numbered 23, in July the number was more than double, 55, and in August it was just trebled, 69. The cool of September and the slowing down of work brought the cases down to 36.

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Food.—It is, of course, a fact well known to pharmacologists that drugs are absorbed more quickly by the fasting stomach than when administered after a meal, but although almost anyone knows this to be true with regard to medicines, few people realize that it is equally true with regard to industrial poisons. Experience in the lead trades taught the English years ago that one of the best preventatives of lead poisoning was the presence of food in the stomach, and in English lead works it has long been customary to supply the workmen, free of cost, a glass of milk or a cup of cocoa the first thing in the morning, and in their more recent industry of anilin dye manufacture the English follow the same rule. The Germans' experience during the war, when the food blockade demonstrated on an unprecedented scale the effects of lack of food, has proved conclusively that lowering the body nutrition results in a marked lowering of the resistance to poisons.* In spite of the increasing knowledge as to the prevention of poisoning from various explosives which was gained as the war went on, the number of cases of poisoning increased in Germany as the food blockade tightened, instead of falling as it did in Great Britain, in France, and in the United States. In the Düsseldorf district the deaths from DNB poisoning in 1915 were only 7 among 1,603 workmen, or 1 in 230, in 1916 they had risen to 10 among 1,516, or 1 in 150, and in 1917 to 25 among 2,000, or 1 in 80.

This question of the influence of proper and sufficient food in warding off industrial poisoning has received less attention in the United States than one would expect. In all my experience I have known of but one white lead works and one anilin dye works which give milk to the workmen, and in the case of the dye factory it is given only to those employed in the most dangerous department, the one in which dinitrobenzene is handled. It is not usual even in the poisonous trades to find provision for a wholesome hot meal at noon, and the indigestible cold lunch is as customary in American factories where poisons are used as is the lunch room with hot food and hot tea or coffee in the German and the British factories.

Carlson's and Woelfel's (4) experiments with the solvent action of human gastric juice on the basic carbonate of lead and the basic sulphate confirm the practical experience of the British that milk or other food in the stomach minimizes the danger of lead poisoning from the digestive tract. They found that when milk and gastric juice are mixed in the proportion of one to one, lead salts added and the mixture incubated at body temperature for 10 hours, not enough lead goes into solution to give a qualitative test for lead (with two exceptions when white lead paint dust was used). The

* Aduccio found that starvation increases the action of cocain, strychnin and phenol; Jordan, that starvation increases the action of digitalis. (Kobert, p. 26.)

same results were obtained in mixtures of hydrochloric acid 0.05 per cent and milk. But when the ratio of gastric juice or HCl to the milk was increased, the lead salts were dissolved in proportion to the increase in the quantity of gastric juice or HCl.

"This action of the milk is probably due to the fixation of the HCl by the milk protein and the neutralization of the HCl by the carbonate of milk. Hence when an excess of milk is added to the gastric juice there will be no hydrochloric acid to effect solution of the lead salts, while in the presence of an excess of gastric juice some free hydrochloric acid remains to act on the lead. We are inclined to the view that the formation of insoluble lead albuminates is a factor of minor importance in the above action of milk. . . . Albuminous foodstuffs can therefore diminish the solution of lead salts in the stomach only to the extent that they fix the HCl in the gastric juice. . . . The taking of milk is a more efficient prophylactic measure than the taking of an equal amount of other forms of proteins, because there is less appetite secretion of gastric solution with milk and the fat in the milk depresses and retards the action of the gastric secretagogues."

Carlson advises as an important protective measure for lead workers, drinking a glass of milk between meals, say at 10 A.M. and 4 P.M., in order to diminish the chance that the lead they have swallowed be dissolved in the stomach.

Alcoholic Drink.—The influence of alcohol on industrial poisoning is important, although not so important as is generally supposed by employers, managers and foremen. I believe there is no form of industrial intoxication in industry, from lead to carbon disulphid, which I have not heard attributed to alcohol, no matter what the clinical picture might be. Even physicians often assure me that the lead, or mercury, or anilin, or naphtha poisoning, about which I am inquiring, never occurs in sober men, only in alcoholics; yet if they would copy the careful methods used by Tanquerel des Planches (5), a century ago, they could easily convince themselves, as he did, that many men who lead sober, righteous and godly lives, suffer as severely as the drunkards. (See page 14.)

Nevertheless Tanquerel admits the influence of alcohol on lead poisoning and points to the records of the Charité Hospital in Paris where the largest number of cases of plumbism came in on Tuesday and Wednesday, a fact which he attributes to the debauch of Sunday. Pieraccini(6) says that lead and alcohol make up a vicious circle, for alcohol favors plumbism and plumbism increases the craving for alcohol. It is certainly true that many lead workers believe that beer "cuts the lead and carries it off," because it washes away the disagreeable, sweetish taste in early plumbism better than any other drink.

Much more striking is the effect of alcohol on the palsy of mer-

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curialism and the cerebral symptoms of nitroglycerin poisoning, and of poisoning from sulphuric ether, from anilin, nitrobenzene, trinitrotoluene and other coal tar compounds. This is treated in detail in the sections on these poisons.

Anemia, Nephritis, etc.—Certain constitutional defects are generally regarded as rendering a person unfit for employment in poisonous trades. Thus damaged kidneys will make elimination of the poison more difficult, anemia will add to the danger of benzene poisoning, and of plumbism, anilism, etc., which involve loss of red cells. This is a field which still waits for thorough investigation, and until that is done we are dependent on *a priori* reasoning only.

Influence of Race.—Experienced foremen and employers of labor believe that there is a difference between colored and white men with regard to their susceptibility to certain industrial poisons. The Negro is generally held to be especially resistant to those poisons which affect the skin, causing various forms of trade eruptions, and also to those poisons which gain entrance through the skin. Thus in the making of dye intermediates and coal tar dyes it is said to be desirable to employ Negroes in the preparation and handling of such substances as paramitranilin and dinitrochlorbenzene because they are not subject to the distressing dermatoses from which white men suffer when they do work of this sort. I have also been told that Negroes can work with anilin, with dinitrobenzene, and with the nitrotoluenes with less danger of systemic poisoning than can white men. Some foremen even maintain that in dealing with these poisons, which enter through the skin, men of fair complexion will be found more susceptible than men of dark complexion.

Actual experience during the war proved that the skin of the Negro is not so sensitive to irritating chemicals as is the skin of white men. Marshall, Lynch, Smith, and Williams, of the Chemical Warfare Service, tested the susceptibility of white and of colored men to mustard gas. A certain degree of resistance was displayed by about 20 per cent to 40 per cent of the whites, but by 78 per cent of the colored. Two per cent of the whites showed excessive sensitivity, but none of the Negroes. In a study of TNT poisoning in six nitrating and shell-loading plants, by the National Research Council, it was found that Negroes suffered far less from TNT dermatitis than white men (1). It was not, however, possible to prove that their susceptibility to systemic poisoning was slighter, although this was the opinion held by the men in charge of the two plants in which colored men were employed. In one of these, a shell-loading plant in Virginia, Te Linde found no case of TNT sickness among the Negroes. Those who were working in the same departments with white men sometimes showed, by the Webster reaction in the urine, that they had absorbed TNT, but the urinary changes

were never as marked as in the case of the white men, nor did the colored men complain of any symptoms of poisoning.

On the other hand, Herman and Putnam, working in a nitration plant in Pennsylvania, found no difference in the susceptibility of the two races. In examining 37 white men and 13 Negroes, they found some cases of marked poisoning among the latter, indeed the most typical case of TNT poisoning that they saw was in a Negro. These observations were of more value than those made in shell-loading plants, because in the latter Negroes and whites were in only rare instances employed in the same department, while in the nitration plant they worked together. Besides this, the Negroes in the Virginia plant lived in their own cabins, the whites in company barracks with the company canteen, and the Negroes were much more cleanly in their habits, more willing to take baths than were the mountain whites. In the Pennsylvania plant the two races lived and worked under the same conditions.

This disappearance of the apparent difference in susceptibility between the two races when they are placed under the same conditions was found by the French also in munition plants during the war. According to Roger G. Perkins (7), there were three races employed in producing and loading the French explosive m  linite, a mixture of picric acid (trinitrophenol), and dinitrophenol, the latter of which proved to be very poisonous. At first it seemed that the yellow race, the Annamites, were decidedly the most resistant, and the whites the least so, with the blacks occupying the middle place. Later on, however, the French concluded that the differences between the yellow race and the white could be accounted for on other grounds than that of racial susceptibility. The white men were more intemperate, more uncleanly in their habits, and less obedient to shop discipline than were the yellow men, and in addition the most expert medical supervision was given to the white men, resulting in a more careful diagnosis and the detection of earlier cases.

On the other hand, Negroes are held to be more susceptible to lead poisoning than white men. This is an opinion generally held by lead men who employ both races. It has never been possible to prove or disprove this theory by actual figures and it may be that it rests on the fact that Negroes are more likely to develop the brain form of plumbism, lead encephalopathy, than are white men. Edsall (8), found that there were three encephalopathies among six cases of plumbism in Negroes in the Episcopal Hospital in Philadelphia, a larger proportion than has ever been recorded among whites. I have had opportunity to study only two lead trades in which both colored and white men were employed, in making of white lead (9), and the smelting of lead (10). In both, the proportion of encephalopathies among the Negroes was strikingly

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high. There were nine cases of lead encephalopathy in the white lead industry during the sixteen months from January 1st, 1910, to April 30th, 1911. At that time only 15 per cent of the employees were Negroes, but four out of these nine cases of lead convulsions were in Negroes. In lead smelting during the year 1912, the only plants in which there were large numbers of cases of encephalopathy were the three in which the very dangerous Scotch hearths were in use with their extensive dust collecting system, also fraught with unusual danger. In these smelters 875 white men had had 22 cases of encephalopathy, making a rate of 1.3 per hundred employees per year, and 110 Negroes had had 15 cases, or 6.8 per hundred. In order to make the comparison between the two races in a single plant, the records of white and colored men engaged in the three most dangerous departments, the Scotch hearths, the flues and bag house, and the sublimed white lead department, were compared, with the following result: among 84 white men there were 4 cases, or 4.7 per hundred; among 75 Negroes there were 15 cases, or 20 per hundred.

As for the difference between various white nationalities I have found no statement in the literature except one by Legge and Goadby (11), who tell of a lead factory in England in which the Italian workmen seemed to possess decidedly more resistance to lead than the English workmen, but they attribute this difference to habit not to nationality, for it seems to persist only so long as the Italians keep to their own diet and avoid excessive alcoholic drink.

Influence of Sex.—It is to the literature on lead poisoning that one must turn for material on the question of sex as a factor in industrial poisoning. British observers who have had much experience with women exposed to lead in the white lead industry and also in the glazing, finishing, and decorating of pottery and tiles, hold that women not only succumb more quickly to lead but suffer more severely from its effects. Oliver (12), says, "So far as occupation exposure to lead is concerned my opinion is (1) that women are more susceptible than men; (2) that while female liability is greatest between the ages of 18 and 23 years, that of men is later; and (3) that while females rapidly break down in health under the influence of lead, men can work a longer time in the factory without suffering, their resistance apparently being greater." He states that there were in 1897, 328 men employed in the white lead works in Newcastle-on-Tyne, and 571 women. During six months of that year 19 men were reported as having lead poisoning, a rate of 1 for every 17 employed, and 66 women, or 1 for every 8 or 9 employed, just double the rate. The report of the factory inspection department for 1910 shows that in the Staffordshire potteries there was twice as high a rate of plumbism among the women dippers as among the men dippers.

In the United States women have never been employed in large numbers in the lead industries and very few really dangerous occupations are carried on by women, with the exception of litho transfer work, and even this has of late years lost much of its danger through the improvement of machinery. Women work at soldering machine parts and tin cans, and making molded lead articles; they also finish type by hand; but the only industry in the United States in which a study has been made of the comparative susceptibility of the two sexes to lead poisoning is in the glazing and decorating of pottery and tiles. An investigation of lead poisoning in potteries was made by me in Trenton, New Jersey, and in the East Liverpool and Zanesville regions of Ohio in 1912 (13), and it brought to light a high rate of lead poisoning among the women as compared with the men, but a closer analysis threw doubt upon the part played by sex in this difference.

The pottery industry in the United States falls into two divisions: the so-called white-ware potteries which are organized in a strong trade union, and the art and utility potteries and tile works which are unorganized. The women are entirely unorganized in both fields. In the white-ware potteries, the contrast between the two sexes was striking. There were only 39 cases of lead poisoning among 796 men, or 4.89 per hundred, and 29 cases among 150 women, or 19.3 per hundred, but the women had many handicaps aside from that of sex idiosyncrasy. They were unorganized, underpaid, poorly housed, poorly fed, subject to the worry and strain of supporting dependents on a low wage, while the men made high wages, were sure of their jobs, and lived comfortably. In the unorganized pottery fields, however, in the tile works and art and utility potteries, the men and women were in the same economic class, all making low wages with everything that that implies, and no appreciable difference was found there between the two sexes with regard to susceptibility to lead. Among 304 men there were 48 cases of lead poisoning, or 15.78 per hundred, and among 243 women there were 28 cases or 11.52 per hundred, a slightly lower rate, but then the women averaged a shorter period of employment than the men.

In discussing this question with the physicians of the Zanesville district I found that several of them had more men patients with lead poisoning, recognized as such, than women. The typical gastric form of plumbism seemed to be more frequent among the men, but there were large numbers of women and young girls with less pronounced and characteristic symptoms, such as obstinate constipation with profound anemia and sometimes amenorrhea. These were not usually listed as cases of plumbism, as they would be in British records, and this is probably the explanation for the discrepancy between the figures from American and British potteries. However, it is certainly true that economic conditions have an influence on

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industrial lead poisoning and that when the two sexes are working under the same conditions and living in the same way there is no such great contrast between them as is found when the men are well paid and the women poorly paid.

In 1921 the United States Public Health Service published the report of an investigation made by Newman, McConnell, Spencer, and Phillips (14), of the occurrence of lead poisoning in the pottery trades of New Jersey, Pennsylvania, Ohio and West Virginia, which was far more thorough than my earlier one. As a result of examinations made on 1436 men and 373 women they found that, although men are far more exposed to lead in this trade than women, there is more plumbism among the women than among the men. It is true that the rate of "positive and presumptive" lead poisoning among the men was 14.2 per hundred, among the women, 11, but the low rate for women depends upon the shorter exposure of women and the slighter degree of exposure. When one estimates the length of exposure of the two sexes and compares the rates for men and women engaged in the same sort of work, the greater susceptibility of women is clear. The average length of exposure of the "positive" male cases was 17 years, of the female cases, 9.3 years, while for the two "presumptive" groups the figures were 15.7 years and 6.3 years. "It should also be mentioned that in most plants the length of day for the female worker is from one-half hour to one hour shorter than that of the male worker. It would seem that the female reaches these stages of lead poisoning in about half the time required for the male to reach them." Comparing the men and women who work side by side in the dipping rooms, it was found that 58 male ware-carriers had no positive cases of plumbism, while 62 women doing the same work had a rate of 4.8 per cent. Among 71 male dippers' helpers the rate of plumbism was 8.4 per cent and among 149 female dippers' helpers the rate of plumbism was 14.4 per cent.

The figures given by Prendergast (15), collected from the Staffordshire pottery district do not show the difference in rate between the two sexes, but the difference in the form which lead poisoning assumes. Women suffer more from lead convulsions and lead blindness, men suffer more from colic and palsy. His table is based on 640 cases:

	<i>Men</i>	<i>Women</i>
Colic	77.6 per cent	69.8 per cent
Paralysis	57.0 per cent	30.0 per cent
Lead Convulsions	15.0 per cent	34.9 per cent
Blindness (total)	2.3 per cent	7.7 per cent
Blindness (partial)	3.5 per cent	10.2 per cent

This greater liability of women to lead convulsions and other forms of encephalopathy came to light in my study of the pottery

industry in this country as well. In 1911 there were 1100 men employed in lead processes in the potteries which I investigated, and 87 cases of lead poisoning had occurred among them during that year, a rate of about 8 per cent. During the same year there were 57 cases among the 393 women employed, a rate of 14 per cent. The proportion of encephalopathy in the male cases was only 1 in 17, in the female cases 1 in 4.5.

In a study of the lead trades made by an Austrian Royal Commission in 1909, the question of women's employment in lead work was taken up and the Commission urged strongly that it be forbidden by law. They based their opinion on their findings in the typographical trades in which the women had a much higher rate of poisoning than the men. The rate among men type-setters was one in 35 employed, while among the women type-founders and founders' helpers it was one in nine. These figures were brought forward at the International Association for Labor Legislation in 1910 and again in 1912, and the stand taken by the Austrians was vigorously seconded by the Italians under Carozzi, while it was combated by the British, who contended that the Austrian figures, applying as they did to quite different occupations, were not comparable. Type-founding, done by women, involves much more exposure to lead than does type-setting, done by men. The Italians were unable to present proof of the greater danger to women employed in the printing trades in their country, and the British maintained that it was not advisable to rule women out of this industry, to which their powers are well adapted, unless more definite proof of injury could be produced.

It was not possible during the war to draw any conclusions in this country as to sex susceptibility toward trinitrotoluene, for the employees in American plants were almost all men and when women were employed it was never in the most dangerous occupations. In England the mortality from TNT poisoning was greater among the women than among the men, 28.6 per cent of the reported cases, as against 20 per cent among the men, but the women were younger than the men, and Legge believes that their over-susceptibility is explained by their youth, not by their sex.

The record in the German munition plants, where men and women were employed in contact with dinitrobenzene, the most important of the explosives used by the Germans, showed quite unmistakably the greater susceptibility of women to this dangerous trade poison. The men in these plants were a selected group, incapacitated for military service by age or physical defect, or convalescing from wounds in battle. The women were an average working class group. The advantage, therefore, should have been on the side of the women who were not selected for their inferiority as were the men, yet there was more "DNB sickness" among them than among the men.

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In the Düsseldorf district, the proportion of cases of poisoning among the men in 1916 was 56.7 per hundred employed, among the women 66.0 per hundred. Then in 1918, when the food blockade was in full force and all were suffering from malnutrition, the cases among the men rose to 100.5 per hundred, but among the women the figure was 119 (2).

Another poison encountered in the making of munitions during the war, which seemed to cause more suffering in women than in men, was sulphuric ether, used in the manufacture of smokeless powder. It is evident that the British found the experiment of employing women in such work unsuccessful, for the report of the Chief Medical Inspector of Factories and Workshops for the year 1918 states that the women who were introduced into smokeless powder work during the war suffered so much more severely from ether fumes than the men that it was necessary to put men in their place.

The effect of ether upon the girls and women employed in the American smokeless powder works will be described in detail in the section on sulphuric ether. It is sufficient to say here that a much larger proportion of the women than of the men felt the acute effects of the ether. While 48 of 80 women had one or more attacks of acute ether poisoning, only 9 of the 35 men experienced any acute discomfort of this kind and 4 of these described it as so slight as not to interrupt their work at all. An examination of the blood made under the direction of Dr. George R. Minot showed decidedly more deviation from the normal in the girls than in the men.

Influence of Age.—The younger the patient the smaller the dose is the rule in medical practice with, of course, some striking exceptions. Since we know of no such exceptions among the industrial poisons, it is safe to conclude that boys and girls are more susceptible to them than are grown people. This fact has long been accepted in European countries and legislation governing the dangerous trades forbids the employment of children or young persons in processes exposing them to poisons even when the danger is, to the American view, very slight. For instance, one of the least dangerous of the lead trades is printing, yet in Germany there is a prohibition against allowing boys to blow out type cases; in Norway they may not sweep the floor of a printing shop; in Denmark they are forbidden to work in the stereotype department; and the Austrian governmental report of 1909 advised that no young person be allowed to do any work which would bring him in contact with lead. The British experience with TNT in the early years of the war showed clearly the greater susceptibility of the young people. The general mortality from toxic jaundice was 25.9 per cent of the reported cases, but for persons under eighteen years of age the proportion was six deaths out of nine cases.

We have very little data in the United States with regard to the greater susceptibility of young people to industrial poisons, partly because we have not, up to recently, employed many young people in such processes. Nevertheless, it is a subject which should be dealt with by legislation before the evil becomes greater. Our experience in shell-loading plants during the war showed that the younger men working with TNT suffered more from the effects than did the older men (1). In one very badly managed loading plant the custom was to discharge the men as soon as they showed signs of poisoning severe enough to lead the doctor to believe that the company might get into trouble. Of all the men who were discharged on account of sickness during one month, one-third were under 25 years of age, while the proportion of the entire force which belonged in that age group was only one-eighth. In the better managed factories, which were studied, the contrast between the older and younger men was not so striking but was clear. For instance, in one plant 48 cases of TNT poisoning fell into two groups, one consisting of 29 lads under 21 years, the other of 19 men over 30 years. The older men had averaged 49 days of work before they fell ill, the younger men only $10\frac{1}{2}$ days. Similar results were obtained in a TNT nitration plant, the older men averaged 56 days' exposure before they showed symptoms of poisoning, the younger men only 7 to 8 days. In these two plants the men under 25 years constituted less than 40 per cent of the force, but the fifteen cases of most rapid and serious poisoning were all in men under 25 years, most of them being 21 years old or less.

Benzene has recently come into increasing use as a solvent for rubber, shellac, cements, etc., and is now used by young men and girls as well as adults. There are no trustworthy data on the proportion of cases of benzene poisoning among the forces employed in any factory nor on the comparative severity of the poisoning in the young and in the mature, but it is perhaps significant that out of 34 severe cases of chronic poisoning in the literature 25 were in "young persons," and out of 19 deaths, 15 were in this age group. Five were under 16 years of age. It seems obvious that benzene poisoning, with its tendency to hemorrhage, must be especially dangerous for menstruating girls and pregnant women. (See chapter on benzene.)

Among the occupations which should be forbidden to women and to lads under 18 years are the following, according to a recent decision of the International Labour Bureau: Production and use of solder with more than 10 per cent lead; melting lead or zinc scrap on a large scale; mixing and pasting in making or repairing storage batteries; cleaning rooms in which lead smelting and refining, zinc smelting, the preparation of oxids, and of lead colors and lead enamels and glazes, is carried on.

Individual Susceptibility.—Idiosyncrasy was understood by the Greeks to mean so peculiar a mixture of body fluids that the introduction of a drug would cause an abnormal reaction, either overgreat or over-slight. Not only might the reaction to a drug be abnormally marked but a reagent which caused no injury to a normal person might set up symptoms in those with an idiosyncrasy, and this idiosyncrasy was held to be inborn, often hereditary. We no longer talk of a peculiar mixture of body fluids, but we are no nearer than the Greeks to an explanation of the familiar phenomenon of one person reacting to rag-weed pollen, another developing hives after eating strawberries, another asthma because of the proximity of a horse. Nor can we explain why there is such a difference in the susceptibility of different individuals to the same industrial poison. All we know is that two men will be working at the lead pot, the one will be taken and the other left; two women will be spreading benzene cement, the one will be taken and the other left.

Tanquerel des Planches emphasized the great variation in susceptibility to lead that he had observed in different individuals. He says that "temperament does not count. The sanguine, the nervous, the lymphatic, are about equally susceptible." Among his 1217 cases of plumbism, 424 were originally strong and vigorous; 584 were of medium strength; and only 208 were of feeble constitution. Alcohol and want of cleanliness have something to do with it, but "cases are not rare where persons of regular and sober lives have worked only a few days or months when they were attacked with colic."

It is easy to collect instances of over-susceptibility to industrial poisons and I have included many in the case histories in the following chapters. Lead, arsenic, methyl alcohol, benzene, all these exhibit marked variations in their action on different individuals. The men forming the crew of a submarine are all exposed to exactly the same concentration of hydrogen arsenid fumes for exactly the same length of time, their reactions to the poison cover a wide range. A construction gang in a steel mill is caught by escaping carbon monoxid gas, some die, others are only moderately gassed. Four men are imprisoned for a few minutes in a room full of ammonia fumes, one dies in 15 minutes, another after two hours, the third lives till the next day, the fourth recovers.

In the lead trades a great variation in susceptibility is always noted. In the early days, 1911, I visited a very dusty white lead works, and the man who was my guide told me he had worked there ever since he was twelve years old, for 32 years, and had never been poisoned, although at times he had been unable to see across the room for the thick lead dust. Yet in this same plant another man sickened at the end of two weeks and died of acute plumbism at the end of less than six months. Among 186 sanitary ware enamelers,

equally exposed to lead enamel dust, the majority averaged over five years before severe plumbism developed, but 21 succumbed after less than six months. Among 167 smelter workers who had plumbism, were 18 who came down with lead poisoning in less than three weeks, the rest averaged more than three months. I have the record of a white lead worker in a dusty plant who went to the hospital with acute lead poisoning after three days' work only, and of a bath-tub enameler who came down with colic after four days.

Others react with unusual severity, as for instance a vigorous young Slav who had never been sick in his life before and who was employed in work not considered particularly hazardous, pouring lead glaze over roof tiles. After five months his appetite was gone, he was losing weight and strength, at the end of two months more he was seized with a sudden agonizing colic, fainted and when he recovered consciousness, passed into a violent delirium during which he was evidently suffering severely. This was followed by two weeks of mental confusion and impaired vision and when I saw him three months later he was still pale, nervous and weak and not yet able to go back to work. Dr. Stybr, of Pittsburgh, reported to me a case which he had seen in 1910, in an enameler of bath-tubs. He was suffering from acute plumbism with colic when he came to Dr. Stybr, and was under treatment ten weeks before he could go back to work in May. In September Dr. Stybr saw him again, and this time he had complete double wrist drop, partial paralysis of the tongue and of the muscles of the throat and larynx, and his mentality was distinctly clouded. He died the following February.

It is safe to say that there is no feature of industrial poisoning so troublesome to the physician as this difference in susceptibility. If only it were possible to determine once for all the minimum dose of a poison which could possibly give rise to symptoms, the whole problem of prevention would be so much simpler. Unfortunately the industrial physician must face the fact that in any large group of men or women there will be some individuals whom he cannot possibly recognize when he makes his initial examination, who do not betray themselves in any way, but who sooner or later are destined to fall victims to a quantity of poisonous dust or vapor which has no effect on the rest. It will be very hard for him to get his employer to see this, for the practical layman believes that what is dangerous for one man must be dangerous for all. He knows that a spurt of molten metal will burn any man it strikes; a falling scaffold, a current of electricity, a bursting fly wheel, these do not injure one and spare another. The damage is in direct proportion to the exposure. Why then, he argues, should one man get lead poisoning from work over a melting pot when twenty men in the same room do not show the slightest sign of ill-health? Yet this same employer recognizes the everyday fact that in any epidemic of any

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kind a large proportion of the population is not taken sick. Even at the height of the great influenza visitation the victims were always in the minority. If a village with 500 inhabitants has its water supply infected with typhoid bacilli, there will not be 500 cases of typhoid fever, there may not be 50. But if there are no more than five, the infected water is responsible and not some innate depravity in the five individuals.

Even animals show a great variation in their susceptibility to poisons, yet they cannot be accused of alcoholism, or dyspepsia from eating pie, or late hours and excessive dancing, or any of the other sins against personal hygiene so comforting to the worried employer. Stieglitz (16), who worked with rabbits and guinea-pigs, trying to produce experimental plumbism by spraying a solution of lead acetate into the cage, found that not only did the animals vary with regard to the severity of the poisoning but also with regard to the localization, for in some the kidneys suffered most, in others the blood vessels, and in others the central nervous system. The same sort of evidence is given repeatedly by Lehmann and his colleagues, to whom is due so much of our knowledge concerning the action of toxic industrial gases, and indeed it may be said to be the universal experience of animal experimenters.

It is important, however, to be sure that a rapidly developing case of industrial poisoning is really due to idiosyncrasy and not to an accident or a neglect resulting in an excessive exposure to the poison. A few years ago the investigation of any lead industry in the United States seemed to bring to light a large number of over-susceptible men who had developed serious poisoning after only a short exposure, but a closer study always showed that, while some of them might have sickened quickly because of an idiosyncrasy to lead, the larger number had to be attributed to an excessive exposure to lead dust or fumes. For instance, an article was published in 1898 by Hobbs (17), of Omaha, telling of his experience with the employees of a very dusty white lead plant. He saw 26 cases develop after an exposure of less than six months, some of no more than two weeks. Some twelve years later when I visited this same plant, I found that there was still a large number of cases of rapidly developing plumbism. One-half of 120 recent cases of acute plumbism had developed after less than two months' exposure, and 68 per cent after less than six months. This proportion is far too large to be explained on the ground of individual susceptibility; the really over-susceptible were probably the men, some 6.6 per cent of the whole number, who became poisoned in less than two weeks' time, one of them after only three days.

In the same way one must distinguish between the excessive exposure and individual susceptibility in the men of another dangerous lead trade—smelting and refining in neglected and poorly con-

structed plants. In 1912 one very badly managed western smelter had 167 cases of fairly severe plumbism, and no less than 72 per cent of these men had succumbed after an exposure of less than six months. Here the over-susceptible men may have been the 37 who were poisoned after less than eight weeks' work. Hall's (18), report of lead poisoning in the American Smelting and Refining Company's plant at Aguas Calientes, Mexico, shows that excessively bad conditions in a lead smelter can bring about even more rapid poisoning than this, for the flue dust men in that plant sometimes developed acute symptoms after 72 hours' work and were usually incapacitated at the end of eight to ten days.

Hirt (19) tells us that from 20 to 30 per cent of all lead workers are not susceptible to lead and that of the remaining 70 to 80 per cent, something over one-half become poisoned very quickly, the others more slowly. The only accurate figures I was able to obtain on this point in an American lead trade showed a smaller proportion of non-susceptibles than Hirt's. There were two very dangerous white lead factories which I visited in 1911 and in which every man was given a medical examination at least once in a fortnight. The records showed that 35 per cent of all of the men in one factory had plumbism, and 28 per cent of all in the other factory. However, when I omitted the newer employees and included only those who had been employed as long as one year, I found that the rates were 52 per cent and 40 per cent. Only 10 per cent in one factory and 12 per cent in the other had been able to resist the effects of lead for as long as eight years.

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CHAPTER 2

LEAD PATHOLOGY

LEAD came into use very early in the history of civilization and its poisonous effects were soon discovered. Greek, Latin and Arabian physicians knew that lead would cause colic if swallowed. Dioscorides, in the first or second century after Christ, accurately described not only lead colic but paralysis, following the swallowing of lead, and also knew that breathing lead fumes would cause the same disorder. He spoke of the mechanical devices used in his day by workmen to protect themselves from lead fumes. His "molybdania" is supposed to have been litharge. Pliny used the word *minium* in its present meaning of red lead, and white lead was known to the famous Arabian alchemist, Geber.

It was the widespread use of lead as material for cooking vessels and other household articles that caused the most notorious outbreaks of lead poisoning, except in France, where it was the custom to promote acid fermentation in wine by adding lead to it. Since Poitou was the region in which this custom prevailed the name of "colic of Poitou" was given to lead colic. Stockhausen in 1656 published at Goslar a treatise declaring that Poitou colic was caused by lead, and he drew an accurate picture of clinical plumbism. The principal source reported in early days in England was lead-contaminated cider, and in Spain there was much poisoning from the use of lead to line cooking vessels. The best work on the subject of industrial plumbism was done in France in the early part of the nineteenth century, culminating in and overshadowed by the epoch-making treatise of Tanquerel des Planches, (1) "the Columbus of lead poisoning." Tanquerel had abundant clinical material; for there were received at the Hospital of La Charité in Paris between 1831 and 1839 no less than 1217 cases of lead colic. White lead work was responsible for 406 of the cases; painting for 382; red lead and massicot making, for 75; color grinding, for 68; potteries, for 61; lapidaries, for 35; refining, for 25; German glazed card making, for 11; making lead salts, for 10; and fifteen other trades had less than 10 each. Tanquerel saw also arthralgia in 755 cases, paralyzes in 127, and encephalopathy in 72. Tanquerel's clinical observations were very accurate, and not much of importance has been added to them. He also noted what has escaped many industrial physicians since his day, that severe poisoning could always be traced to lead

vapors or emanations. Only relatively mild and slow poisoning followed contact with solid lead or lead paint. He even tried to settle the question of lead absorption through the unbroken skin by experiments with two dogs and a rabbit, but he did not succeed in poisoning them, and he was sceptical as to the possibility of lead poisoning ever occurring in that way.

The pathological anatomy of lead encephalopathy interested Tanquerel, and his contributions to this field are valuable. He also confirmed Bright's observations on the connection between chronic plumbism and contracted kidney.

After Tanquerel, a vast amount of clinical data on industrial plumbism was collected in Germany, England and France, and during the latter half of the last century the pathological anatomy was the subject of much study, especially in Germany. The field which still awaits a thorough exploration is the pathological physiology and chemistry of lead poisoning, the exact mode of absorption of lead, the changes it undergoes in the body, its mode of action, its storing and excretion and the changes it produces in the tissues. Much work has already been done in this field, but with results which are more or less contradictory or unconvincing.

Vascular System.—In a work of this kind only a brief résumé can be given of what has been done in the field of research into the pathology of plumbism, *i.e.*, the changes in body fluids and tissues which underly the clinical symptoms. While no organ or tissue remains quite unaffected by the presence of lead, if this be prolonged, the action of lead is generally believed to be exerted primarily, not on the organs but on the vascular system.

According to most authorities the underlying pathology of chronic lead poisoning is a structural change in the blood vessels. Ever since the researches of Maier (2), and his pupils in the early eighties it has been held that lead circulating in the blood sets up changes in the walls of the smaller vessels, consisting essentially in an endarteritis and a periarteritis, and that these produce a loss of elasticity of the vessel wall, the formation of multiple aneurysmal dilatations, thrombosis, or rupture with hemorrhage, and as a consequence, slow starvation of the tissues whose blood supply is progressively diminished. The well-known lesions of chronic plumbism, contracted kidney, atrophy of the optic disc, apoplexy, and progressive paralysis of the insane, are attributed to structural changes in the vessel walls.

Not only the lesions of chronic plumbism, but the symptoms of the acute forms, lead colic and encephalopathy and blindness, transient or lasting, are traced to the action of lead on the vessels, to the production of a vaso-constriction resulting in temporary ischemia, with passive congestion and edema. Such a vaso-constrictor spasm is seen as the cause of the dry, anemic brain found in some cases of encephalopathy (Elschnig (3)), or the "patchy

edema" of Oliver (4), or retinal ischemia, edema or hemorrhage. Cases of fatal encephalopathy with no anatomical lesions (Westphal (5)), of transient blindness with no structural change in the retina (Elschnig (3)), are also explained thus.

Kussmaul and Maier (6) published in 1882 their much quoted findings in a case of chronic plumbism. The man affected had been a painter for many years, and had several acute attacks of plumbism, in one of which he died. They found in the stomach endarteritis, thickened mucosa, and atrophy of the glands, with a marked proliferation of the connective tissue. These changes were still more marked in the intestine where the walls of the vessels, the small arteries in particular, showed thickening of the coat and narrowing of the lumen. Around the arteries of the brain they found a slight periarteritis. Later Maier's pupils found pathological changes, including multiple aneurisms, in the vessels of the central nervous system (Dressler), of the kidneys (Hoffa), and of the intestines (Gesenius).

Jores (7), endeavored to confirm the findings experimentally, but was quite unable to produce in rabbits any chronic lesion of the blood vessels, even after prolonged administration by mouth of lead acetate (from 2 months and 9 days up to 14 months and 20 days). None of the changes in the vascular system described by Maier and his pupils appeared, no fatty degenerations in fresh or in hardened specimens, no endarteritis or aneurysm or rupture, but only a uniform dilatation, very marked in the small vessels of the mesentery and stomach. These dilatations, Jores thought, probably encouraged the formation of thrombi from the products of the destruction of red blood corpuscles.

As to the exact nature of the vascular change set up by the presence of lead in the blood there was much controversy. The earlier pathologists, Rosenstein (8), Hitzig (9), Henle (10), believed that the circulatory disturbances set up by lead were caused by a direct irritation of the non-striated muscles of the vessel wall, while French experimenters hold that the effect on the vessels is secondary, and that the primary action of lead is exerted on the adrenal cortex (Gouget (11), Bernard, and Bigart (12)), causing hypertrophy and histological changes. Siccardi (13), however, succeeded in producing vaso-constriction in the veins and arteries of large mammals by bathing them in lead solution. He could provoke a progressive intense constriction proportional, within certain limits, to the dose employed, and never preceded or followed by a dilatation. This constriction could be overcome by lavage followed by atropin, another proof that the action is on the muscles of the median coat. With the aid of sulphuretted hydrogen, Siccardi claims to have demonstrated lead in this coat. He produced the same constriction in vessels treated *in situ*, more marked in the vessels of kidney and

liver than in the musculo-cutaneous. In spite of this vaso-constriction, Siccardi found the action of lead predominantly depressant on the blood pressure except for a transient rise after a minimal dose, and this he explained by its action on the isolated heart; for in minimal doses lead lowers the functional activity of the heart, affecting tonus, energy and rhythm, and leading to arrest in diastole. Since this effect is neutralized by adrenin and not by atropin, Siccardi concludes that in the heart the action of lead is exerted directly on the heart muscle.

The changes in the vascular system in chronic poisoning are such as follow repeated, excessive vacillations in the blood pressure (Thoma (14)). The proliferative endarteritis is probably reparative and compensatory to the damage done to the muscular coat, but, as usually happens in such repair processes, the changes may be out of all proportion to the damage in the media. The sub-endothelial connective tissue proliferates and then undergoes fatty, hyalin, and calcareous degeneration, resulting sometimes in complete occlusion of the vessel. A very striking case of obliterative endarteritis was described recently by Timme (15), in a painter who suffered from senile gangrene of the feet to a degree necessitating amputation. The vessels in the feet were found to be occluded and lead was isolated from the atrophied muscles.

Brain.—The study of the anatomical basis of the cerebral form of plumbism was eagerly pursued during the latter half of the last century, and it was in this field that the greatest contributions were made to the understanding of the mode of action of lead. We are indebted to Westphal not only for brilliant work on the pathology of cerebral plumbism, but also for a thorough review of the work which had been published prior to 1888. Briefly it may be abstracted as follows: Kussmaul and Maier were the first to make a microscopic examination of the brain (all of Tanquerel's observations, largely negative, were of the gross anatomy only) with the result mentioned above,—the discovery of periarteritis of the cerebral vessels and a slight narrowing of the lumen of the smaller vessels in the cortex. Von Monakow's (16) study, which is widely quoted, was made on a case of progressive general paralysis, and he found changes typical of progressive paralysis of the insane, namely, a marked atrophy, especially of the frontal and parietal regions and of the brain stem. Microscopically, there was in the atrophied areas an increase of the adventitia of the vessels, with cell proliferation and infiltration, fat droplets and pigment. There was also atrophy of the nuclei of the hypoglossus and the trigeminus. Seiffert (17) found atheromatous plaques in the basilar arteries, with thickening of the pia and enlargement of the lateral ventricles. In Oellers's (18) case there was an obliterative endarteritis in the vessels of the optic nerve, the retina, and the choroid, and Oppenheim (19) found a

fresh hemorrhage in the brain and an apoplectic cyst. His case was one of coma, delirium, and left-sided hemiplegia.

Westphal's theory is that there are at least four ways in which lead may exert its effect on the brain. First, there is a direct action which is shown through general cerebral symptoms or through focal changes. He places here those peculiar neuroses which are accompanied by hemianesthesia and psychic disorders, and which may at the same time show focal anatomic lesions in the cerebral nerves, most commonly the optic. Second, comes the effect of lead on the blood vessels of the brain, an arteritis with its sequelæ, hemorrhage and encephalomalacia. Third, is the effect of lead on the kidneys, which may cause uremic symptoms, and fourth there is a combination of these. The next comprehensive review of the pathology of cerebral plumbism is Quensel's (20), published in 1902. He finds in the literature descriptions of six cases of cerebral plumbism without any lesion beyond edema or anemia; five with vascular lesions or hemorrhage; and eight with changes characteristic of dementia paralytica, *i.e.*, atrophy of the cortex, chronic inflammation of the meninges with adhesions, hydrocephalus internus and externus, ependymitis, etc. The occurrence of fatal encephalopathy without demonstrable lesions in the brain is noted also by Oliver who, on the basis of his own observations, says that the usual finding is marked pallor and dryness of the brain, which is hard and inelastic, with flattened surface, or perhaps with edema.

Such an encephalopathy and amaurosis with no anatomical findings is to be attributed either to high arterial tension or to toxemia. The former explanation is favored by most observers. Thus Elschnig (3) says that he has seen spasmodic ischemia of the retina in a case of transient lead blindness, and endarteritis, with atrophy of the disk, in a case of permanent blindness. He believes that these two illustrate two stages of the same process; for as Thoma has shown, intense variations in the blood pressure result in thickening the vessel walls. Mosny (21) and his pupils reported a case of transient blindness, lasting twenty-four hours, due probably to arterial spasm localized in the occipital region. There was homonymous hemianopsia, and it was accompanied by marked mental torpor and weakness which cleared up as the blindness passed over. The pupillary reactions were normal and there were no changes visible in the eye grounds.

A case of this kind came to my notice in Cincinnati and was seen at autopsy by Dr. Paul Woolley. The patient was a young Negro who developed acute encephalopathy while employed in a white lead factory. After showing vague prodromal symptoms he fell unconscious in the street and died without recovering consciousness. Dr. Woolley reported that the brain was anemic and very dry, but otherwise normal with no evidence of arteriosclerosis in any of the arteries

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of the gray matter. There have also been cases of encephalopathy apparently uremic in origin, yet at autopsy no granular kidney was found. Here, according to Miller (22), the underlying pathology may be a vascular spasm resulting in deficient renal function. He quotes Hughes and Carter as having shown that the uremic symptom complex may occur without any kidney lesion. Ménètrier (23), who saw a case of saturnine encephalopathy developing during a colic, in a young pewter polisher, believed that it was a cerebral uremia, caused primarily by high arterial tension, in spite of the absence of changes in the kidneys; for the most striking symptom was the high arterial pressure, especially just before the convulsion came on. Since no atheroma was found at autopsy or any change in the adrenals, he believed that the lead had acted directly on the vasomotor nerves. Traube's (24) theory was that lead encephalopathy is always uremic, but Tanquerel insisted that the absence of nephritis is one of the characteristics of true lead encephalopathy.

The presence of lead in the brain has led men to think of a possible toxic action directly on the brain cells. Quensel found 19 cases in the literature in which lead was isolated from the brain, the earliest being Empis' and Robinet's in 1852. Jolly (28), Oppenheim, Herrmann (29), and Trimborn (30) hold to this view, as does Westphal, so far as the causation of neuroses and hemianesthesias are concerned.

Wynter Blyth (25) found in the brain of a man dying of lead poisoning with pronounced cerebral symptoms 105.77 mg. of lead, estimated as sulphate, and in another with similar symptoms, 117 mg. Goadby (26) examined the brain of an eighteen-year-old girl who died of lead encephalopathy after nine months' employment in making litho-transfer papers. All the vessels were engorged and there were capillary hemorrhages. From 250 g. of brain tissue 46.6 mg. of lead was recovered. Oliver also has had lead isolated from the brain after death from lead encephalopathy but he insists that in other cases quite as typical as those in which lead is found, the search for it may be fruitless. Quensel holds that such a negative result is not conclusive; for experience shows that lead may be unequally distributed through the various parts of the brain, and may be lacking in just the part selected for analysis.

A toxic action of lead on the ganglion cells of brain and cord is said to occur in experimental and in clinical lead poisoning. Nissl (31) claims to have produced in rabbits with subacute plumbism lasting ten days, changes in the cells of the anterior horns, disappearance of the Nissl bodies, stippling of the protoplasm, shrinking and distortion of the nucleus, which turns into a pale, homogeneous, shapeless mass. He found later similar changes in Purkinje cells. Ceni (27) found in a man who died in coma, atrophy, edema, and anemia of the cerebrum, and degenerative changes in the ganglion cells (Marchi's and Golgi's methods), especially in the large pyrami-

dal cells of the deeper layers of the cortex in the neighborhood of the vessels, the walls of which were for the most part not thickened, but full of fat granules. Spiller (42) quotes observations made by McCarthy on dogs poisoned with lead acetate. There were degenerative changes in the cortex, most marked around the gyrus cruciatus, which corresponds to the motor area of the cortex in man. The nerve cells were degenerated, the capillaries of the cortex increased, their walls thickened, surrounded by accumulations of cells, and there were small hemorrhages into the cortex.

G. B. Hassin (32), in a recent article, describes the difference between epidemic encephalitis, which is of infectious origin and resembles in its pathology paralytic dementia, and the toxic group, represented by lead. The first is an infiltrative encephalitis, characterized by excessive, widespread, perivascular and sometimes parenchymatous infiltrations, the pia-arachnoid changes being quite mild. Lead encephalitis, on the other hand, is a productive process, characterized by proliferative phenomena in the mesodermic tissues (blood vessels, capillaries, and the pia-arachnoid). The study of the pia-arachnoid is of great importance; for these structures may exhibit changes, even when the brain tissues proper appear normal.*

Spinal Cord and Peripheral Nerves.—The study of the pathology of lead palsy has revealed degenerative changes in the peripheral nerves and in groups of muscles supplied by them, in the anterior root ganglia and in the motor cells of the anterior horns of the spinal cord. Which of these lesions is primary, and whether lead palsy is a toxic neuritis, or the result of toxic injury to the motor-trophic cells of the anterior horns, *i.e.*, a poliomyelitis anterior, is a question concerning which there was active controversy for many years.

The earlier pathologists held to the latter theory, the central origin of lead palsy. Thus Vulpian (34) claimed to have produced in dogs a saturnine chronic poliomyelitis anterior with progressive spinal paralysis. Even tabes was in some cases attributed to lead. Redlich (35) of Vienna found among 100 cases of tabes four in which lead was a possible etiological factor, and in one of them he thought syphilis could be definitely excluded. Other observations of this kind followed the publication of his article, but as all were made before the introduction of the Wassermann test they were later rejected. In 1892, Eichhorst (36) came out for the primary neuritis theory, on the basis of a case in which the degenerative changes were confined to the radial nerve, with muscles and spinal cord intact. Remak (37), who at first had held lead palsy to be caused

* An interesting experiment was made by Camus (33) who injected extremely small doses of lead chlorid (one or two c.c. of a 2-1000 solution) into the cerebrospinal canal of dogs, between the atlas and the occipital bone. For two days nothing happened, but then came increasing excitability, hallucinations, convulsions, and death. No such result followed similar injections into the white matter of the brain.

by a chronic cervical poliomyelitis anterior, because of the peculiar distribution, later went over to the theory of the peripheral character of the palsy, as did also Oppenheim. Yet as recently as 1900 Gordon (38), who saw a case of lead palsy of the muscles supplied by the ulnar nerve, those forming the thenar and hypothenar eminences, followed by atrophy of the interosseous muscles, held that it was not a primary degeneration of the ulnar nerve but a progressive muscular atrophy of spinal type.

Gombault and Charcot (39) called lead palsy a special form of peripheral neuritis, segmentary and periaxial, the axis cylinder escaping damage and normal segments of nerve trunk being found above and below the damaged ones. Therefore, in contrast to Wallerian degeneration with involvement of the axis cylinder, the neuritis of plumbism is curable. Mme. Déjérine-Klumpke (40), who in 1889 described progressive muscular atrophy in plumbism, held that it is due to a combined lesion of the anterior roots, the cells of the anterior horns, and of the peripheral nerves.

Stieglitz (41) tried to clear up the question as to the peripheral or central origin of lead palsy by experiments on ten rabbits and thirteen guinea-pigs which he poisoned by means of a spray of lead acetate. He did produce palsy in four and cerebral symptoms in eleven, but there were changes not only in the anterior horn cells but in nerves and muscles as well. He also found the posterior roots more or less degenerated and he insists that in man there must be damage to the sensory fibers or how explain the occurrence of arthralgia, which is so common that Tanquerel found it in thirty-five per cent of all cases?

Kobert's (42) opinion is that in most cases of lead palsy there is a polyneuritis saturnina, a primary disease of the peripheral motor nerves set up by lead and inducing a degenerative atrophy of nerve fibers which is followed by degeneration and atrophy of the muscles supplied by them. He admits, however, that in some cases, such as Vulpian's, von Monakow's, and Oppenheim's, there does seem to have been a primary inflammation involving the anterior horn cells. He gives Prévost and Binet credit for first producing experimentally a peripheral motor neuritis through the administration of lead.

Spiller (43) examined the brain and cord of a man of 48 years who died of lead encephalopathy, with palsy of the upper extremities and weakness of the lower. He found in the cord no degeneration of the white matter, but intense degeneration of the anterior horn cells, of the cells of the cervical and lumbar regions. The roots were little altered, but there was very marked degeneration of the median nerves (Marchi and Weigert stains) and an increase of nuclei between muscle fibers, *i.e.*, an interstitial myositis. It was quite impossible to decide in what order these changes had occurred.

At a joint meeting of the Philadelphia and New York Neurologi-

cal Societies, December 18, 1909, Mitchell (44) presented a case of typical amyotrophic lateral sclerosis with bulbar symptoms in a painter 53 years old, with no evidence of lead in his system at that time. There was no change in sensibility. He died, and Cadwalader (45) made the autopsy. The patient had had many attacks of colic, palsy of the hands, difficulty in walking, indistinct speech, difficult swallowing, marked atrophy of all four limbs, muscular pains, and increased reflexes. Microscopically, there was pronounced disease of the anterior horn cells and degeneration of the lateral columns. In the cells the change was atrophic with the perinuclear chromatolysis so often found in primary cord disease; but the severity of the disease in the anterior horns did not bear any definite relation to the intensity of degeneration in the lateral columns, and it was not possible to determine which was primarily affected.

C. A. Herter and Ira Van Gieson (46) reported before the New York Neurological Society in 1895 the history of a case of lead paralysis with the histological changes in the nervous system and the distribution of lead in the body. The man, who was 26 years old and who had been a painter for several years, was poorly nourished and undersized. He was first admitted to the city hospital in February, 1894, with double wrist drop and severe colic. On November 23d he was again admitted, this time with nausea and colic, weakness in the arms and legs, a marked lead line, and atheromatous arteries (moderate alcohol, no syphilis). There was complete loss of power in wrist and finger extensors on both sides and little power in flexors; atrophy of all the muscles below the elbow, especially the interossei; slight ankle drop; feeble knee jerks. On December 7th he became drowsy and then fell into a muttering delirium with pin-point pupils, eyes prominent, respiration stertorous, pulse feeble, skin clammy. The urine contained casts, epithelial and granular, and albumin, and was low in urea while the urea content of the blood was two to three times the normal. The man died on December 12th. Van Gieson examined the nerves (in osmic acid) and found the following: in the ulnar nerve, about one fiber in ten moderately degenerated; in the external peroneal, one in four; in the sciatic, one in ten; in the left external cutaneous, three in ten; in the right radial, one in twenty; in the left plantar, one in twelve. In the spinal cord few cells were destroyed, but in sections stained with anilin dyes degenerative changes were revealed in about one-third of the ganglion cells, such as vacuoles, and breaking up of chromophilous granules. Lead was found in the blood, in the central nervous system and organs, the spleen and kidneys containing most, the liver and spinal cord following.

Laslett and Warrington (47) made a careful study of the spinal cord and of certain nerves and muscles of a young painter who died after suffering for some time from double wrist drop and extensive

muscular atrophy. They found marked atrophy of the posterior interosseous nerve, with quite half of the fibers gone; less marked atrophy of the ulnar; and distinct atrophy of the anterior spinal roots of sixth, seventh and eighth dorsal segments of the cord; while the posterior roots were normal. There was a marked atrophy of the extensor muscles, affecting over 90 per cent of the muscle fibers, which, however, retained their cross striations. Connective tissue was greatly increased. The interossei were less altered. "Muscle spindles and their nerves, derived from the posterior roots, were normal." No change was seen in Marchi and in Weigert preparations of the cord, but protoplasmic stains brought out alterations in the anterior horn cells, such as eccentric, shrunken nuclei, disintegration and dispersion of chromatin bodies, and even chromatolysis. They hold that such changes are secondary to the atrophy of the axones of the cells (the *réaction à distance* of Marinesco), in this case chiefly affecting the cells of the sixth, seventh, and eighth segments, from which the axones of the interosseous nerves are derived.*

Kidneys.—The study of the kidney of chronic plumbism has produced much evidence in favor of the view that plumbism is essentially a disturbance of the vascular system, functional in the acute, structural in the chronic. As early as 1827 Bright (48) noted the connection between plumbism and albuminuria, Tanquerel mentioned it in 1839, and in 1863 Ollivier (49) confirmed their observations on human beings by producing changes in the kidneys in animals and demonstrating lead in the urine.† Wagner (50), in 1882, described saturnine nephritis as a special variety of contracted kidney, fifteen of his 150 cases being traceable to lead. Four of the fifteen had also arthritis urica.

According to Strümpell (52) the kidney of plumbism is the "genuine contracted kidney," an extremely slow and chronic but constantly progressive atrophy of renal tissue and its substitution by cicatricial tissue. Kobert says there is no metallic poison which has so characteristic an effect on the kidney as lead. The excretion of even small quantities exerts an injurious effect on the cells of the parenchyma, destroys them, and eventually sets up a true cirrhosis, which, according to v. Leyden (53), is identical with Virchow's atrophic granular kidney. The first stage is one of typical glomerular ischemia, with very marked secondary degenerative changes in

* Hyslop and Kraus (*Arch. Neurol. and Psychiat.*, 1923, 10, 444) review the literature on the pathology of lead paralysis and point out that lesions have been found in every part of the neurone, from the cord to the muscles. The term, peripheral neuritis, is therefore inaccurate and they suggest instead, "toxic neuronitis."

† The typical kidney of chronic lead poisoning has never been reproduced in animals, doubtless because the exposure to lead can never be prolonged for years as it is in human beings. (Jores (7), von Jaksch (51), Kobert (42).)

the parenchyma, and, as it goes on, there is an endarteritis obliterans, involving especially the smaller vessels (Volland (54), Mohr (55), and Stachelin (56)). There is also sometimes a subacute form of renal plumbism, with marked edema, and here the pathological changes are mixed; for there is not only thickening of the vessel walls with occlusion of the lumen, but a marked degeneration of the convoluted tubules. The endothelium of the glomerular loops thickens, and hard shining hyaline masses result. It is especially in the very finest vessels that these changes come out most clearly. The later stages of the lead kidney conform absolutely to the type of secondary contracted kidney. The process is one of repeated vaso-constrictor spasm of the renal vessels, then endarteritis, then ischemia, dropsy, degeneration of the epithelium of the convoluted tubules, and then, as the narrowing and occlusion of the vessels proceeds, proliferation and contraction of connective tissue (Volland).

It is characteristic of the contracted kidney of chronic plumbism that it may exist for years without giving any sign and may betray itself first by an uremic encephalopathy. The urinary findings are what one expects from such a pathology,—abundant urine low in solids, absolute diminution of urea, as well as of uric acid and of phosphoric acid, but symptoms of urea retention may not appear for a long time. Albumin may be absent and the microscope may show only hyalin castes, few leucocytes, rarely red blood cells. There is hypertrophy of the left ventricle of the heart in such cases, but usually this is not discovered till the heart begins to wear out. Later, the right heart enlarges. Uremia supervenes when the heart can no longer overcome the obstacles to circulation in the kidney, either because of cardiac overstrain or of extension of the process in the kidney. Dropsy may be entirely absent, and indeed it is commonly said to be, but in the later stages it appears in the ankles and below the eyes. Headache, before the onset of uremia, may come from the high blood pressure, causing active, cerebral hyperemia. Albumin-uric retinitis, with hemorrhages and white spots in the retina, has been repeatedly described in chronic plumbism. Von Jaksch finds always in chronic lead poisoning an increase in formation and excretion of uric acid which is an evidence of increased breakdown of nuclein bodies, caused, he believes, by lessened oxidation. Arthralgias and gout are explicable on the ground of retention of uric acid and its salts. Lüthje (57) rejects this explanation of saturnine gout, and holds that lead has no influence on the excretion of uric acid, and does not cause uric acid retention, but increases uric acid production, as shown by the abnormal quantity of the latter in the blood.

Preti (58) found, in three chronic cases, that the total elimination of purin bases was over the normal, and, even on a purin-free diet there was an excess of uric acid in the blood (Götze (59)). Ram-bousek (60) fed rabbits with white lead by stomach tube and found

in all an increase in total purin excretion, rising strikingly as the symptoms of poisoning increased. The increase in uric acid was not constant, appearing in the early stages, but not in the later, and apparently ceasing when real injury to the kidney had occurred, as shown by albuminuria. These disturbances of elimination he believed to be the direct effect of the lead, and not an indirect action induced by the production of structural changes in the kidneys.

Gastro-intestinal Tract.—The gastro-intestinal symptoms are the most striking of all in ordinary acute lead poisoning, and yet the pathology of lead colic has not been the subject of nearly so much study as have other features of plumbism. Animal experiments are of limited value; for typical lead poisoning in animals is characterized by diarrhea, not by constipation (Harnack (61), Meillère (62)). That lead colic is preceded by constipation and accompanied by extreme contraction of the intestine is notorious, and the clinical treatment is based on this fact. As to the exact mechanism of these contractions, however, and their relation to the colic, opinions differ. The action of the lead may be a local irritation exerted directly on the smooth muscle fibers (Eulenberg (63), Guthmann (64), Hitzig (65)), or a stimulus to the nervous apparatus which governs the intestinal movements, causing in animals diarrhea, in man, obstinate constipation (Harnack). The pain is usually accounted for by the violent spasm of the smooth muscle of the gastro-intestinal wall, but by some it is believed to be a neuralgia of the sympathetic system.

The fact that the blood pressure is heightened during colic and that both pain and hypertension are relieved by amyl nitrite, led Pal (66) to assume a specific irritation of the vasomotor nerves of the abdominal sympathetic, with constriction of the intestinal blood vessels as the cause of colic. Albertoni (67) and Annino (68) and Ruffino (69) find the origin of such vaso-constriction in the action of lead on the vasomotor center. Kobert made experiments on animals in the warm chamber with the abdomen open and came to the same conclusion as Pal, namely, that lead causes an intermittent irritation of the nerves of the intestinal blood vessels and of the muscular walls. Atropin and scopolamin, which have a paralyzing action on the peripheral ends of these nerves, act like a charin on lead colic.

Siccardi (13) criticizes most of these investigators on the ground that they have studied the indirect effect of lead in the circulating blood instead of its direct local action in the intestinal tract. In order to correct this error he observed the action of the neutral acetate of lead on the isolated intestine, choosing this compound because like all organic salts it is poorly ionizable and therefore has little action on albumin. He employed Magnus' method of registering the movements of the intestines of a guinea pig immersed in Ringer-Locke solution at 38° C. The rhythmic contractions being

well maintained, he could detect the slightest variations when introducing an isotonic solution of the lead salt in varying quantities. Fifty such observations were made on the small intestine, colon, and rectum, as a result of which Siccardi declares that lead in the intestinal tract exerts two effects: one on the movements of the intestine, and one on the tone, these actions varying according to the dose and the part of the intestine involved. The changes in intestinal motility consist first in a lowering of tone with diminution of rhythmic movement, but this hypotonicity, under the influence of an accumulation of lead, yields suddenly to a state of hypertonicity with arrest of rhythmic movements which persists till the lead is eliminated. In this way constipation passing into colic is produced. Siccardi was, however, unable to say whether the mechanism which produces lead colic is a direct action on the smooth muscle fibers, or on ganglia or nerve ends, or on all simultaneously.

Rigel (70) studied 200 cases of lead colic and decided that there was a toxic vaso-spasm of the abdominal vessels, due to an irritation of the vaso-constrictor nerves, the pain and the contraction of the intestinal wall being secondary. Walko (71) refuses to accept this explanation; for he has seen a normal or even a low blood pressure during colic, so that vascular spasm cannot be responsible, nor can spasm of the intestinal musculature be responsible; for the muscles may be actually atonic. He believes that it is a neuralgia of the mesenteric plexus, as was suggested by Romberg (72), similar to the lead neuralgias in the limbs. Debove (73) explains lead colic as a neuralgia of the celiac plexus and quotes a thesis of Levatier, who succeeded in producing sclerotic changes in the solar ganglia in animals by the administration of lead, and who also saw similar changes in man. Excitation of the fibers of the celiac plexus affects the smooth muscles of intestine, vessels, uterus, etc.

Years ago Tanquerel found in one of his autopsies a striking enlargement of the abdominal ganglia of the sympathetic, which were two or three times their normal size. Then Küssmaul and Maier found proliferation and contraction of the connective tissue of the septa of several ganglia of the sympathetic, especially the celiac, in a man who died during an attack of lead colic. Mosse (74), working on the ganglia of lead poisoned rabbits, found distinct degenerative changes in the cells, but since similar changes could be produced by other drugs which have the property of setting up intestinal contractions, such as berberin, he concluded that these changes were the result, not the cause, of the colic. He subjected the ganglia to analysis in Salkowski's laboratory and was able to show the presence of lead. The actual pathogenesis of lead colic remains, therefore, still an unsolved problem.

In chronic lead poisoning Küssmaul and Maier (6) found a thickening of the submucous coat of the stomach and intestines (due

to connective tissue proliferation and to thickened vessel walls), endarteritis, and atrophy of the glands, plaques, and follicles of the jejunum, ileum and the upper part of the colon. Maier (2) also succeeded in producing experimentally a cloudy swelling of the glandular cells in the stomach; later granular and fatty degeneration; numerous ecchymoses; thrombosis of arteries, veins, and capillaries; thickening of the submucous coat. Similar but less striking changes appeared in the intestine. Kobert speaks of a gastritis glandularis with disappearance of glands, and thickening of the walls of the stomach. McJunkin (75) found in animals a necrosis of the gastric epithelium and of the cells of upper parts of the glands, which reached its height at the end of twenty-four hours, and then gave way to a regenerative process with proliferation of epithelium and phagocytosis of the necrotic cells. This process, well established at the end of 48 hours, was complete in 72 hours.

Walko, whose work on the gastric pathology of lead poisoning has already been quoted (71), concluded that at the beginning of the disease there is a functional disturbance which shows itself in a lessening or complete disappearance of acid and ferment formation, and further in a heightening of the activity of the stomach, which is succeeded by a diminution of motility. These disturbances are very obstinate and protracted, but are usually purely functional, rarely accompanied by parenchymatous changes in the mucosa, and partly affected by constipation and by disease of the gastro-intestinal nerve plexus. Preti (58), examining the gastric juice during colic found anaclidity or hypoacidity, and Allevi found the same condition.

Blood.—Lead causes a secondary anemia, which is seldom of a pronounced type, the blood count usually running between four and five million and the hemoglobin 80 per cent or over. (See chapter on lead diagnosis.) The changes in the white cells are not characteristic and most students of the blood picture in lead poisoning do not find striking changes in the red cells.

In Cadwallader's (76) blood examinations both micro- and macrocytes were commonly seen, and in 33 of his 37 cases there was always at least one normoblast. Myeloblasts were seen in only two, one of which presented an unusual picture,—no less than 130 normoblasts and 13 megaloblasts (to 500 whites) and yet the red cell count was reduced only one-fourth.

Cabot (77) says that in lead poisoning there may be an extraordinary number of nucleated reds, and this, in the absence of any other evidence of severe anemia, such as achromia or poikilocytosis. Among these nucleated red cells a very considerable proportion, occasionally a majority, may be megaloblasts. Simon and Spillman (78) also find megaloblasts in experimental poisoning, yet there are cases of extreme anemia in which these youthful forms are lacking,

showing that the hemopoietic tissues no longer respond to the call for fresh corpuscles. Thus in the very interesting case described by Wolff (79) of a man dying after more than ten separate attacks of lead poisoning, the hemoglobin had fallen to 40 per cent, the red cell count to 1,250,000, and there were no immature forms to be found.

It is the presence in the blood of more or less abnormally staining red cells which has attracted great attention and has been the subject of lively controversy. These cells are polychromatophilic or reticulated or "stippled," *i.e.*, filled with granules which take up basic stains. The granules appear when the blood is stained by Wright's method, or by any other basic stain, as fine or coarse granules, sometimes so fine and so closely packed together as to give the appearance of a purplish discoloration of the protoplasm; sometimes as dots of coarse granules, few in number; sometimes as both powdery and coarse grains. These stippled cells have been interpreted in many ways, but the clearest description of their origin was first given by Craik (80) and his findings have recently been confirmed and elaborated by Key and by Aub and Reznikoff.*

Craik, who was studying malaria, noticed incidentally the appearance of polychromatophilic cells in men under the influence of lead. He administered lead acetate to patients who were suffering from mild infection. Four days after the dose was given he could find young forms of the parasite, rings, in normal red cells and in polychromatophilic cells, but only young forms were ever found in the latter. The later stages of the parasite, amebic forms, and large pigmented forms, were found only in normally staining cells with or without stippling. Craik thinks that this shows that within 24 hours the polychrome cell has grown to a normal cell and the polychrome stippled cell to a normally staining stippled cell. Polychromasia means premature birth of erythrocytes; punctate basophilia means something more pathologic. Even in mild anemia, the former is rarely absent, but the latter is rarely present in anything but profound anemia, with the exception of lead poisoning. Only when punctate basophilia is seen in otherwise normal blood, associated with but little polychromasia, is it pathognomonic of plumbism.

A loss of elasticity and a heightened resistance to hemolysis has been noted as an effect of lead. At the First International Congress of Industrial Hygiene, held in Milan in 1906, Glibert (81) of Brussels spoke of a marked loss of elasticity of the red corpuscles as a result of lead poisoning, claiming that this was a good diagnostic sign. His statement led Rambousek to look for a heightened resistance to hypotonic and to hemolytic substances on the part of such red cells, but in experimental plumbism he was unable to find any

* *Harvard Lead Studies*, not yet published when this goes to press.

change toward hypotonic salt solution and the resistance to hemolytic substances, saponin and potassium hydrate, was actually lowered. According to Rambousek, Roulens reported analogous findings at the Congress of Hygiene in Berlin in 1904. Four years later, at the Second Congress of Industrial Hygiene in Brussels, Meillère stated that he had found in lead poisoning an increased resistance to hemolysis and he placed this phenomenon among the diagnostic signs of plumbism. Hayem (82) finds increased viscosity of the blood and loss of elasticity on the part of the red cells. Orban (83) and Malassez (84) find increased resistance to hemolysis.

The recent work of Aub and his colleagues, Anne S. Minot, J. A. Key, Paul Reznikoff and D. E. Smith, has thrown much light on the action of lead in the body, on its absorption, storing and excretion and on the effect of lead on the red blood corpuscles. They have found that lead is carried largely in the plasma of the blood as an insoluble triple phosphate but it is also partly picked up by the red blood cells, uniting with the phosphates of the cell membrane to form insoluble lead phosphate on the surface of the red cells. The effect of this is to make these cells hard, brittle and inelastic, an effect noted, although not explained, by other observers. These red cells break up more easily than do normal cells, which fact explains the high peripheral blood destruction in lead poisoning with the resulting anemia. There is a loss of the normal stickiness of the red cells, a shrinking, even in isotonic solution, a loss of normal elasticity and an increased resistance to changes in external osmotic pressure, but at the same time an increase in the speed of disintegration, "leaded cells break up more readily on standing than do normal cells and are easily fractured by rotation or shaking."

The anemia calls forth the production of young blood cells, reticulated corpuscles, but these under the attack of the lead in the plasma undergo degeneration and this degeneration is shown by basophilic clumping of the reticulum. The so-called stippled red cells are therefore degenerating reticulated corpuscles and they are the result of the response of the blood building tissues to the anemia caused by lead and the destructive action of lead upon the newly formed red cells.

The effect of lead poisoning on the white cells of the blood is less striking and, according to the majority, less constant. Grawitz (85) says that a marked leucocytosis is a frequent occurrence, and there are likely to be numerous atypical forms, giving the blood a "leukemoid" appearance. Key found a leucocytosis in experimental plumbism in rabbits, the increase being chiefly mononuclear, large lymphocytes and large mononuclears. (See chapter on diagnosis.)

Bone Marrow.—Changes in the marrow of the large bones have been described by Jores (7) as consisting in a loss of fat, slight pig-

mentation and increase of cellular elements. In experimental poisoning carried to the point of marked anemia, the disappearance of fat from the marrow and the increase of cellular elements, especially of the hemoblasts, is followed by disappearance of the latter and by a gelatinous degeneration (Raimondi (86), Stockman (87) and Charteris). In Wolff's (79) case there was extreme anemia and no evidence in the blood of any regeneration of cells. The marrow showed abundance of cellular elements, but they were non-granular, and nucleated reds were absent.

The study made by Cadwallader (88) on human bone marrow in severe plumbism yielded interesting results. His case was one of fatal encephalopathy, but unfortunately no blood examination was made before death. The marrow in the ribs and at the ends of the femur was a deep purple, but in the shaft of the femur it was yellow and fatty. Microscopic examination of the head of the femur revealed marked hyperplasia of marrow cells, producing in some places almost solid marrow. The most striking feature was the great number of nucleated red cells which formed large, compact masses. In the center of such a mass the cells were very large, closely packed, and the nuclei showed irregular figures; but at the edges they were looser and smaller, and looked like normoblasts. Between these areas were spaces filled with white cells,—chiefly granular myelocytes, transitionals, few eosinophils and polymorphonuclears, and a moderate number of large and small lymphocytes. The hyperplasia of the leucoblastic tissue produced chiefly granular myelocytes, some of which had karyokinetic figures.

The discovery by Anne Minot* that the greater part of the lead in chronic plumbism is deposited and stored in the skeleton suggested to her the possibility that the anemia of plumbism might be due to the localization of the lead in the marrow of the bones and a consequent injury to the growing red cells. She found, however, that this theory was not borne out by further experimental study. Analyses made of solid bone deprived of marrow, of leaded animals, and of marrow separated from bone, showed that the lead was deposited in the solid shaft, not in the marrow. Moreover, she found that when hens were poisoned with lead the marrowless pneumatic bones of the wings contained a considerable amount of lead. Another confirmation of these findings is the fact that relatively large amounts of lead may be held temporarily in the skeleton without the appearance of anemia.

Spleen.—In the spleen, Jores (7) found the most marked change to be (in experimental poisoning) a massing of blood pigment in the cells of the pulp. Yet, in spite of the great quantity of this pigment, there is no enlargement of the spleen. Wolff (79) found

* *Harvard Lead Studies*, unpublished.

in the human spleen a myeloid change—the presence of numerous nucleated red cells, which were lacking in the bone marrow.

“Endlessly varied and complicated is the picture of chronic lead poisoning,” von Jaksch has said. “Always that part of the body suffers most which has been the seat of some previous disease, whether it be kidneys, central nervous system or vascular system. It is impossible to explain all the manifestations on the ground of the action of lead on one tissue only, such as on the smooth muscles, the vessel walls, the nerves of the sympathetic system; but there are certain tissues which seem to be especially susceptible to its effects, —namely the vascular walls, the bone marrow, the motor neurones, and parts of the sex organs.” (89)

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CHAPTER 3

ABSORPTION AND EXCRETION. QUANTITY

ABSORPTION AND EXCRETION

THE mode of entrance of lead into the body is of the greatest practical importance; for it is obviously impossible to have an intelligent system of protection against lead poisoning unless there is a clear understanding of the relative danger of absorption through the skin, absorption through breathing lead dust, and absorption through stomach and intestines of lead which is carried into the mouth with food or tobacco. We must be able to say whether the prevention of dust and fumes is more important than the prevention of actual contact with lead and its compounds, and whether lead poisoning is best combated by provisions for bodily cleanliness or by provisions for keeping the air of working places free from lead.

Absorption through the skin is apparently possible, especially when lead is mixed with oil as it is in paint. The question has been a difficult one and observations in industry have helped little in settling it, because it is impossible to rule out other channels of absorption in industrial cases, nor are the results obtained by animal experiments entirely conclusive; for they cannot be made to apply to men without reservations. Such experiments have been carried on ever since Tanquerel's day, the latest work being that of Süßmann (1) one of Lehmann's assistants, who published his experiments in 1922. He estimated the lead in the discharges of cats and guinea-pigs after anointing them with lead oxide mixed with animal fats, all possible precautions having been taken against the entrance of lead through the mouth. Süßmann decided that lead was absorbed, because he found it in the feces and urine, but the amount was not large enough to cause poisoning except of a very slow and chronic type. Brezina and Eugling (2) in 1912 believed that they had succeeded in making lead pass through the skin of guinea-pigs anointed with lead in lanolin. They took the appearance of stippled cells in the blood as proof of the absorption of lead.

A. S. Minot (3) injected subcutaneously doses of 220 mg. of a sterile suspension of lead carbonate into six cats. These animals were kept in metabolism cages and though no attempt was made to obtain total recoveries, the lead excretion in urine and feces was studied from time to time. Small amounts of lead (2 to 3 mg. per

week) were constantly excreted in the feces and occasional traces appeared in the urine. After four months, during which the only indications of lead intoxication were definite lead lines in certain of the animals, two of them were killed and their tissues analyzed. The total amounts of lead found in the body, aside from the still unabsorbed deposit at the site of injection, were 25.72 and 29.2 mg., respectively. Of this, about 90 per cent was in the skeleton, most of the remainder, in the liver and gastro-intestinal tract.

It appears from experiments such as these that it is possible to make lead pass through the skin of an animal into the subcutaneous tissue and that lead can be slowly absorbed from the subcutaneous tissue and distributed throughout the body, finding its final lodgment chiefly in the skeleton. If this can be shown in animals kept under observation for a few months only, the possibility of chronic lead poisoning in man through skin absorption cannot be denied. Painters who have their hands and forearms smeared with white lead in oil for eight hours a day and for many months out of the year may be assumed to absorb from the skin quantities of lead which are probably very small but which throughout the years slowly accumulate in the skeleton. As we shall see presently, a slow, continuous stream of lead, even in minute quantities, can set up the changes characteristic of chronic plumbism.

Whatever be true of the possibility of skin absorption of lead, its practical importance in industry is slight compared with the importance of absorption through the inspired air or even absorption of lead which is conveyed to the mouth on food or tobacco by handling it with lead-smeared fingers. This latter mode of poisoning has always been emphasized by employers and foremen, and the responsibility for an attack of lead colic placed upon the individual workman who supposedly should protect himself by careful washing of his hands and face. There is no practical evidence that this mode of poisoning is of much importance. It is true that a small amount of lead may reach the mouth from the fingers, but except in the case of painters, the men who get lead on their hands are almost always exposed also to lead dust and fumes in the air, and the incidence of poisoning can be traced with much more positiveness to the latter source. Even with painters the dust caused by dry rubbing is a factor far from negligible.

I know of but one occupation in which lead poisoning by direct ingestion is of common occurrence. This is the work of the commercial artist, or "retoucher," who touches up the shadows and the high lights of photographs for catalogues, advertisements, etc., in order to make them reproduce better. These men and women use a fine camel's hair brush and white lead paint, and many of them have the habit of putting the brush in the mouth to bring it to a point. They sometimes suffer from very severe forms of lead poison-

ing, especially as many of them do not know that the paint they use contains lead.

Among European authorities there has been practical agreement for many years that the great danger for the lead worker comes from contamination of the air by lead dust and lead fumes, which are essentially the same, lead fumes being merely a suspension of very finely divided lead compounds. Almost a century ago Tanquerel emphasized this, saying: "All the characteristic traits of the primary effects of lead may be quickly observed in workmen who are habitually in an atmosphere of lead dust and vapors. None of the primary effects are found among the workmen who handle lead in a fixed state and who consequently are never in contact with an atmosphere where particles are disseminated. . . . All those individuals who are habitually in the midst of an atmosphere filled with lead particles or emanations are liable to lead encephalopathy." Tanquerel even went so far as to say that lead palsy is found only in those whose work exposes them to "emanations of lead disseminated through the atmosphere."

A French authority of later years, Breton (4), also lays the greatest stress on the danger of dust and quotes Gauthier's report on lead poisoning in the Department of the Seine from 1900 to 1911, which showed that out of 1,000 white lead workers who had their hands in wet white lead, only 50 became poisoned; but out of 1,000 who handled dry white lead, 105 were poisoned. Out of 1,000 solderers working in an atmosphere full of fine dust and fumes, 280 showed evidences of plumbism.

In England the danger of lead dust is recognized and the preventive measures enforced by the Department of Factory Inspection of the Home Office are directed especially against dust and fume contamination of the air, with brilliant results, as will be evident to any visitor of the potteries of North Staffordshire and of the white lead works in Newcastle-on-Tyne. In the latter city I saw men with their arms smeared up to the shoulders with white lead, but this was not looked upon as a risk because ample facilities were provided for the men to get rid of the lead at noon and at quitting time. Sir Thomas Oliver (5), to whom the reforms in this industry are due, had laid stress especially on dust prevention, and in that year, 1910, only five cases of lead poisoning had developed among 1,320 employed. Some years later when I visited the potteries I saw the same principle applied, of meticulous dust prevention, and here, too, there have been remarkable results. There were in 1913 in British potteries only 62 cases of plumbism among 7,085 employees, a rate of less than one per cent.

Legge and Goadby (6) say that the poisonous nature of any lead compound from an industrial point of view is proportional, (1) to the size of the ultimate particles of the substance manufactured and,

therefore, to the ease with which such particles are capable of dissemination in the air, and (2) to the solubility of the particles in the normal fluids of the body. In short, the toxicity of a lead compound depends first on a physical property—its dustiness, and second, on a chemical property—its solubility.

Teleky says that in a large factory in Austria in which 80 tons of white lead were used in indoor work in a year's time, 163 cases of lead poisoning developed among the indoor workmen, while among the outdoor men who handled almost three times as much, 237 tons, there were only 50 cases. General recognition of the special danger to painters, of the dust produced by dry rubbing of white lead paint, has led to the prohibition of such work in many European countries. I have a list of 100 Chicago painters who were treated for plumbism and who averaged twenty years in the trade, but among them were 11 who sickened in less than one year and these 11 had all been doing interior decoration with dry rubbing. Another comparison can be made between the bag house and flue cleaners in a Utah smelter and the men in the refining department. The former were shoveling and transporting flue dust which contains about 45 per cent * of lead, and 62.5 per cent of these men had plumbism. The refiners were handling pure lead, but there was very little dust, and only 14.3 per cent had plumbism.

The cumulative evidence of the over-weening importance of lead-laden air has had its effect on governmental regulations, and British authorities at present hold that the question of personal cleanliness on the part of the worker is of minor importance, that "very little trouble is brought about by not washing hands" (Goody (7)) and that "unless you can go to the fountain-head of the mischief, the dust, and stop that, you are not going to secure much improvement by all the personal cleanliness in the world." (Legge.) The German smelting expert, Richard Müller (8), estimated that a blast-furnace tapper could breathe as much as 1.0625 gm. of lead in a ten-hour day, but that it was possible to wash off his hands only 0.0876 gm., and of course it is absurd to think that all of that could be wiped off on his food and reach his mouth.

Practical evidence of the supreme importance of the respiratory tract as the channel of entry for lead seems, therefore, to be incontrovertible, but there has been much difference of opinion as to the exact way in which poisoning takes place when dust and fumes are breathed in, whether the lead actually reaches the lungs or is simply caught in the mucus and saliva and swallowed. Meillère (9) holds that absorption through the lungs is of very slight importance, that the gastro-intestinal tract throughout its whole extent is the place where absorption occurs. Many efforts have been made to follow the

* Hoffman, H. O., *Metallurgy of Lead*, New York, 5th ed., 1899, p. 379.

lead introduced experimentally and determine the exact course it follows. Stieglitz (12) poisoned 13 guinea-pigs and 10 rabbits by a spray of lead acetate solution, wishing to reproduce the conditions under which industrial poisoning in man takes place, but it is impossible to accept his experiments as a proof of respiratory absorption because he made no attempt to protect the animals' bodies and he admits that the fur was often soaked with the solution. Lepid-Chioti is said by Roth (13) to have made successful experiments as early as 1880, introducing lead acetate into animals by blowing dry powder through a tracheal fistula and proving that lead had penetrated into the body.

The experiments carried out in K. B. Lehmann's (10) laboratory to determine this point have been very widely quoted; these were both human and animal experiments. Two of Lehmann's assistants, Saito and Gfrori, breathed in powdered white lead, inhaling through the nose and exhaling through the mouth. Saito found that he exhaled 10 per cent of the quantity inhaled, that 51 per cent was caught in the nose, and 3 per cent in the mouth, and the remaining 36 per cent he assumed had passed to the lungs. Gfrori exhaled only 2.8 per cent, and the amount calculated to have reached his lungs was 43 per cent. When they breathed through the mouth they found 15 per cent was caught in the mouth and they believed that the lead in mouth and nose was eventually swallowed with the mucus and saliva.

When, however, they turned to animal experiments, using five dogs and one rabbit, to verify these findings, they obtained quite other results. There were, of course, great technical difficulties which they tried to overcome by placing the animal in a wooden box with his head thrust through a hole into the dust cylinder and fixed there with rubber bands. They introduced the dust through a nasal tube and fastened the lips together to prevent licking. Then the animals were killed and the lead estimated. They found much less in the respiratory tract than they had expected and much more in the intestinal tract. In five of the six animals the respiratory tract contained from four per cent to 24 per cent of the lead, and the rest was in the stomach and intestines, showing that the greater part of the lead that had been blown into the nose and throat had been caught in saliva and mucus and reached the stomach, not the lungs. The sixth animal had 80 per cent of the lead in the respiratory tract, but this result was too exceptional for them to accept.

In this series Saito succeeded in recovering practically all the lead that had been introduced, but in experiments made on two dogs he could find only 14 per cent in one and 40 per cent in the other, because the dogs sneezed a great deal. However, in these animals, also, he found that 88 per cent and 60 per cent respectively of the

lead that had gained entrance to the body had reached the digestive tract.

Goady also experimented in this field, but he came to a quite different conclusion. "That a certain amount finds its way into the stomach direct is not denied, but from experimental evidence we consider the lung, rather than the stomach, to be the chief channel through which absorption takes place." Together with Goodbody (11) he made experiments on 35 cats, animals which are notoriously susceptible to lead, and introduced finely divided lead dust into a closed chamber containing an electric fan to keep the air stirring. Samples of air were drawn off and the amount of lead estimated. Control experiments consisted in feeding cats 7 to 10 or even 20 times the amount which calculation had shown that the dust-breathing animals could possibly take in. Yet these cats which were fed with lead showed little or no susceptibility to poisoning unless alcohol was added to the lead, while the animals breathing lead dust suffered from progressive emaciation and paralysis, and in many instances died with symptoms suggestive of involvement of the brain. Goadby succeeded in demonstrating lead as sulphid in the larynx, trachea, bronchi and bronchioles, by inflating with H_2S and also "by micro-chemical tests with chromic acid and with iodine."

As for the fate of lead in the body, the theory elaborated by Blum, and based not only on his own experiments but on those of many observers, has been generally accepted (14). After a compound of lead is absorbed by the body and reduced to an ionizable salt it is then transformed to an organic compound, to which is due the toxic action. This is probably an albuminate of lead from which the lead is slowly liberated and which is soluble in acids, in alkalis, and in an excess of albumin. The change from a non-absorbable form to an absorbable takes place in the stomach, but absorption occurs in the intestine. Blum was unable to trace its fate in blood and organs, but he succeeded in finding it in the blood of a rabbit three weeks after the administration of lead had stopped. It has, of course, been found in the organs by many investigators, but Blum does not feel sure that its presence there is directly harmful, though it may be that lead enters into combination with the tissue constituents, rendering them "lebensuntüchtig." It can certainly combine with lecithin.

The fact that lead is found in altered tissue does not mean necessarily that it is responsible for this damage; it may have been deposited there subsequently to the damage. On the other hand, quantities of lead have been found in a liver showing no pathological change. Blum believes that the action of lead is to be explained by its "special affinity for certain tissues, the smooth vessels in the muscle walls, the motor nerves, the spinal cord, the blood-building organs, the genital organs." As for excretion, the kidneys play a

minor rôle, the intestines the chief rôle. Blum placed lead iodid and lead oxid in subcutaneous pockets and found that both compounds were changed to the carbonate and excreted in the feces, and that the same thing occurred, only far faster, if the salts were introduced into the peritoneum. He believes that the lead is transported by the leucocytes. It is eliminated partly by the kidneys, but never in large quantities, and sometimes when the body is apparently flooded with lead it may be impossible to find any in the urine. Excretion takes place along the whole extent of the intestinal tract, no matter in what way the lead is administered, whether by the mouth, the respiratory tract, or by the subcutaneous tissues. An interesting confirmation of this was furnished by a non-industrial case of acute plumbism which was described by Kobert. A woman was given a vaginal douche of lead acetate which resulted in her death from acute lead poisoning, and the greater part of the lead absorbed from the vaginal mucosa was found in the intestines.

Many investigations have been made of the organs and tissues of animals experimentally poisoned and of human beings dying from various forms of lead poisoning. The literature on this subject up to 1906 has been collected by Kobert and the reader is referred for this earlier work to his book, "Lehrbuch der Intoxikationen," Vol. 2, Stuttgart, 1906, page 375. Much of the data is conflicting and contradictory, partly because in many cases no analysis was made of the skeleton, partly because the methods of analysis used were not always such as to produce accurate results.

The whole field of controversy over the mode of entrance of lead into the body, the way it is transported, its absorption and storing and excretion, has been illuminated recently by the "Lead Studies" which were carried on at Harvard between 1922 and 1924, by Aub and his colleagues. Fairhall (15) has provided us with a new method of analysis, suitable for the determination of small amounts of lead in biological material,* and the work of Aub, Minot, Key, Reznikoff, Smith and Blumgart has cleared the obscurity from the subject of absorption and storing and elimination. Their investigations furnish an explanation for the clinical observation of Tanquerel and others, that lead which enters the body by the respiratory tract produces its effect much more rapidly and severely than lead which enters by the gastro-intestinal tract. The curious instances of long periods of quiescence, of latency, in lead poisoning, with a

* Fairhall's method of quantitative analysis consists briefly in (a) ashing the organic material at a low heat, (b) precipitating the lead as sulphid from a solution of the ash, (c) reprecipitation of the lead as chromate from a solution of the sulphid, and (4) determination of the lead present by iodometric titration. In this determination the chromic acid derived from the lead chromate precipitate reacts with an excess of potassium iodid, the liberated iodine is then titrated against a standard sodium thiosulphate solution, starch being used as the indicator. This method can be applied directly to the analysis of excreta or of small amounts of tissue.

sudden recurrence of symptoms, is also explained by their experiments.

Anne Minot's paper contains a critical review of the analyses made by Gusserow (1861), Heubel (1871), Ellenberger and Hofmeister (1887), Prévost and Binet (1889), Meillère (1903), and Kiskalt and Friedman (1914). The general conclusion drawn from these studies is that lead tends to become localized and stored in the bones. As for the actual way in which poisoning takes place, Miss Minot quotes as the most significant studies those of Straub and of Erlenmeyer. The "lead stream" theory to explain the fundamental mechanism of lead poisoning was developed by Straub (16) and by Erlenmeyer (17). Both investigators injected lead carbonate or sulphate subcutaneously in cats, the compounds were gradually absorbed and in the course of a few weeks the animals developed chronic poisoning. After death the lead content of the excreta, of the unabsorbed remainder of the deposit at the seat of injection, and the lead content of the bodies of the animals was determined by the gravimetric sulphate method. Most of the absorbed lead was found in the excreta. The tissues, except those close to the subcutaneous deposit of lead, contained only very small amounts of lead. Although there were several unsatisfactory features in these experiments, nevertheless the deductions made by Straub and Erlenmeyer suggest an explanation for the action of lead within the body.

These experimental animals had been severely poisoned, sometimes fatally, during the process of the transportation of lead from the site of injection to the organs where it was later excreted, although at the time of death only very small amounts of lead were found stored in the body. The authors conclude therefore that the toxic effects are due not to deposits of lead at the site of injury but rather to the "lead stream," that is, to the small concentration of soluble lead which is transported in the circulating blood. They point out that the stream is always small, too small to produce any effect were it a single dose, but that as the transportation and absorption continue, innumerable subminimal attacks bring about pathological changes in certain sensitive tissues, and both time and the concentration of this "lead stream" are important factors in the production of toxic symptoms.

Minot's experiments were so planned as to compare the rate of absorption of lead which enters the body through the gastro-intestinal route with that entering through the respiratory tract, and to follow its fate in the body. Carlson and Woelfel (18) had shown that even those compounds of lead which are considered most insoluble dissolve to some extent in the gastric juice. Meillère (9) had asserted that the entire gastro-intestinal tract absorbs soluble lead, although in the alkaline medium of the small intestine and with the hydrogen sulphid often present in the colon a large per-

centage of lead is reprecipitated. This portion, together with what escapes solution in the stomach, represents a large part of all the lead that has been ingested, and probably this part never actually enters the organism but is excreted directly in the feces. Some portion, however, is absorbed even from very small doses, and if these are repeated, enough is absorbed to cause poisoning. The distribution in the body of this absorbed lead was the subject of her investigations.

Minot found it possible to produce chronic plumbism in cats without acute gastric symptoms by administering every other day a dose of lead acetate solution amounting to 50 mg. per kilo of body weight. The cats died or were killed after varying periods, and the lead distribution in the body was studied. It varied a good deal in the different animals, probably because changes of localization of the lead occur at different stages of poisoning; but in all animals the tissue which held the largest percentage of lead was the skeleton, where sometimes as much as 85 per cent of the total deposit was held. In general, the longer the duration of poisoning the greater the proportion of lead in the skeleton. The amount of lead found was a very small proportion of what had been administered, only 5.8 mg. up to 88.9 mg., although amounts running from 1.0 to 11.4 gm. had been administered, which shows that there is in the body a very efficient mechanism to prevent the absorption of lead. Evidence points to the liver as the principal protective mechanism; for when the experiment is shortened, and the animal is killed in the earlier stages, the liver is found to contain a relatively high percentage of the total lead absorbed, this lead having been brought there in the portal circulation. The fact that the quantity of lead stored in the liver does not increase progressively as absorption continues and that the total amount retained in the body is small, points to extraordinarily efficient excretion by the liver. Minot refers to some unpublished experiments by Brady of Harvard who found that the bile is an important path of excretion for lead.

In gastro-intestinal poisoning, therefore, a large proportion of the lead reaches the comparatively invulnerable region of the intestines, liver, and portal circulation. The small amount which escapes excretion in the bile is found chiefly in the bones, which tend to remove it from the blood stream and store it. For example, in the body of a cat which lived for 162 days of experiment, 77.2 per cent of the lead was found in the skeleton; 12.8 per cent, in the muscles; 7.4 per cent, in the liver; 0.6 per cent, in the colon; and the kidneys, lungs and heart had each 0.3 per cent; the stomach, 0.2; and the brain and cord, 0.1. On the other hand, in a cat killed at the end of 18 days the distribution was quite different,—only 40.9 per cent was found in bone, while the liver contained 21.8 per cent; the muscles, 12.4 per cent; the kidneys, 11.3 per cent;

the stomach, 5.2 per cent; the small intestines, 3.6 per cent; the colon, 2.0 per cent; and the lungs, 1.7 per cent.

The question at once arose as to whether, if absorption should cease, all the lead would become localized and stored in the bones as a temporarily harmless deposit. A series of experiments was therefore carried out to test this point and at the moment when the animals, six cats, were severely poisoned and death seemed imminent, the administration of lead was stopped. With no treatment whatever except good care, the cats gradually returned to normal condition, their lost weight was regained within a few weeks, and they seemed well in every way. Two were then killed and their tissues analyzed, and it was found that in spite of the interval of several weeks since the administration of lead had ceased and in spite of the fact that all symptoms of lead poisoning had disappeared and the animals were apparently in a normal condition, a considerable amount of lead was found to be still retained in the body, almost all of it in the skeleton.

DISTRIBUTION OF LEAD IN TISSUES OF CATS KILLED SEVERAL MONTHS AFTER
LAST DOSES OF LEAD BY MOUTH

Cat	Total lead received	Interval since last dose	Total lead found in body	Percentage Distribution of Total Lead			
				Skeleton	Liver	Kidney	Gastro- intest. tract
L	gm. 1.68	days 82	mgm. 20.53	98.5	1.5	00	00
M	11.09	160	97.29	97.0	0.6	1.4	1.0

The contrast between the harmlessness of the stored lead and the marked toxicity of this same lead when it was in process of absorption and transportation gives confirmation to the theory held by Straub and Erlenmeyer that the damage is done not by the stored lead but by small amounts carried in the blood stream.

All this concerns absorption by the gastro-intestinal channel. When the method of administration is by introducing lead dust into the respiratory tract the result is different. Minot succeeded in administering finely divided lead to animals in such a way as to insure its reaching the lungs and prevent its being swallowed with the saliva and mucus. The method used was the following:

"With the animal under ether anesthesia, the neck was opened, aseptically, with as little trauma as possible, and the esophagus securely ligated with four strong linen sutures just below the level of the thyroid gland. The wound was then closed and generally required no further attention. While the animal was still anes-

thetized a small glass tube was inserted, through the mouth, into the trachea nearly as far as the bifurcation. From 1 to 5 cc. of a rather heavy suspension of a lead compound in sterile physiological salt solution (p. h. 7.4) was then introduced through this tube. Less post-operative lung infection has been found to follow the alternative method of injecting the lead suspension through a large needle inserted in the lumen of the exposed trachea. This is probably because bacteria of the mouth are avoided. No leakage occurs, since the elasticity of the tissue completely closes the hole made by the needle. When the lead suspension was in the trachea the cat's head was held high by elevating the cat-board for a few minutes to facilitate insufflation of the particles by gravity."

Since the esophagus was closed, a fact always confirmed at autopsy, there was no possibility of absorption of lead from the gastrointestinal tract. The duration of the experiment was of course limited to the time that the animals could be kept without food. Fluid, however, was introduced daily by intraperitoneal injection, and the animals were well cared for in artificially warmed cages and showed no discomfort except that of fasting and the drooling caused by the inability to swallow. Seven days was the maximum period of survival after operation. Fifteen animals received lead as carbonate, five as oxid, three as sulphid, and two as chromate. In every instance the amount of lead absorbed after a single administration was in striking contrast to the much smaller quantities which would be absorbed in the same period after the swallowing of larger doses of dissolved lead. The quantity of lead found in the tissues, 24 to 48 hours after administration through the lungs of 150 to 200 mg. of solid lead carbonate, is as great as after the administration of several grams of lead in solution during weeks of continuous lead feeding. This fact emphasizes again the marked efficiency of the liver in preventing lead from entering the organism. When it is absorbed by the lung lead at once enters the general circulation, and since only the small portion of blood carried in the hepatic artery goes directly to the liver, the efficient short-circuiting of the lead in the portal circulation of the liver and in the biliary circulation is impossible; instead, all the absorbed lead is distributed by systemic blood.*

Whatever may have been the path of entry, the skeleton always exerts a strong attraction for lead in the blood stream. Because lead absorbed through the lungs enters the general circulation directly, it is more promptly distributed through the organism than that absorbed into the portal blood from the gastro-intestinal tract. This explains the well-known danger of exposure to lead dust in industry. It also explains why the deposit in the skeleton is rela-

* Lead is transported as an insoluble triple phosphate, largely in the blood plasma. See p. 34.

tively greater than after gastro-intestinal absorption of the same duration. In chronic cases following the absorption of lead by either route, the distribution within the body does not differ, and in both modes of absorption there is an almost complete selective localization of lead in the bones.

These experiments have a bearing also on the changes which lead undergoes in the body. A. S. Minot found that after the introduction of lead chromate into the lungs there was a deposit of lead in the skeleton but no trace of chromium could be detected even by the extremely delicate diphenylcarbazide test of Cazeneuve. Evidently the chromate has been dissolved and reprecipitated in the form of phosphate. Such solution could be readily effected only at a hydrogen ion concentration considerably higher than that which is generally found in the body, but it has been shown by Jacobs (19) that it is possible, as a result of the penetration of carbonic acid, for a much higher degree of acidity to develop within cells than in the medium surrounding them, and it is conceivable that conditions might be produced in the phagocytic cells which would be suitable for the solution of the lead particles engulfed by these cells.

The animals which survived longest in these experiments, more than four days after the operation, always showed a different distribution of the lead throughout the body than was found in those dying more promptly. There was still a large percentage of lead in the skeleton, but as much as 12 to 30 per cent now appeared in the liver and the gastro-intestinal tract, which was in strong contrast to the small traces found in these tissues in the earlier experiments. Minot suggests that the explanation may lie in the fact that the animals were fasting and that the acidosis of starvation may hasten the mobilization and excretion of the stored lead.

Aub and Minot (3) found in cases of human lead poisoning that clinical treatment based on this theory would result in increased excretion of lead. Their first report deals with eleven cases of plumbism in men, chiefly chronic plumbism. These patients were at the time excreting no lead, and in some instances there had been no exposure to lead for several weeks. The administration of phosphoric acid was followed by the appearance of lead in urine and feces, and the same was true, but to a much less marked degree, of lactic acid, while potassium iodid had a much slighter effect. In one case of colic with excretion of lead, the administration of magnesium sulphate was followed by a fall in the excretion of lead, while phosphoric acid increased it. A summary of the results obtained showed that more than four times as much lead was excreted in stools and urine under phosphoric-lactic acid treatment than before. The largest amount obtained in 24 hours was 6 mg. The findings of six autopsies bore out the animal experiments and showed that in

human beings also the skeleton is the place where lead is chiefly deposited.

Aub points out the bearing of these experiments on medico-legal problems. If examination of the organs of a person dying of suspected plumbism fails to reveal lead this must not be taken as negative proof, for the bones of the skeleton may be full of lead. On the other hand, the finding of lead in the bones does not prove that lead was the cause of death unless there were clinical symptoms of lead poisoning, in which case it is a valuable confirmatory sign.

Another very interesting series of experiments designed to throw light on the mechanism of poisoning by lead dust were published recently by Blumgart (20) of Harvard. He had found that pituitrin could not be absorbed from the mouth, the rectum, or the stomach, but would be taken up from the nasal mucosa. He therefore undertook to see if particulate matter, such as white lead, could be absorbed in this way. The nasal passages are not only well adapted to catch and hold such particles, but because of their unusually rich blood supply and the close meshwork of submucosal lymphatics they seem well adapted to absorb soluble dust, and perhaps the abundant supply of mucus may exert a solvent effect on the lead salts.

Blumgart used dogs and cats and prevented absorption through any other surface than the nasal by occluding the trachea and esophagus. That this was effectual he was able to prove by subsequent search for lead in the organs below the ligatures, which search never revealed more lead than was to be expected from the usual distribution found by Minot. He then sprayed powdered white lead into the nose with an ordinary nasal atomizer. The animals survived the operation for only 16 to 36 hours. He gives the result of analyses in four animals, using for quantitative estimation Fairhall's method. Lead was found in the skeleton in the following amounts: No. 1, 7.5 mg. metallic lead; No. 2, 22.3 mg.; No. 3, 29.3 mg.; No. 4, 23.3 mg. The liver contained from 0.1 mg. to 1.3 mg.; the internal organs from 0.2 to 0.8 mg.; and the muscles from a faint trace to 0.3 mg.

The lead found in these experiments, averaging 22 mg. of metallic lead, is far in excess of the minimal toxic dose for these animals. It must have been absorbed from the upper respiratory passages and proof is therefore given that here there is a place of ready absorption for white lead dust, at least in cats and dogs. If this be true of animals it must be still truer of man, for it is well known that the natural protection of the human nose against dust is far less efficient than that of the dog's nose or the cat's.

The studies made by Aub and his colleagues furnish an explanation for those cases in the literature of what has been called latent plumbism in which under various conditions, sometimes an acci-

dental injury or an acute illness, sometimes the administration of potassium iodid, the symptoms of lead poisoning appear after a more or less prolonged period of freedom from exposure to lead, or which continue to excrete lead for long periods after the exposure to lead has ceased. Tanquerel described the case of a man who had repeated attacks after several years' absence from lead work. Oliver has reported several instances. One was in a woman who suffered from colic and double wrist drop. She gave up work with lead, and two or three weeks later was admitted to the hospital under another physician, this time suffering from aortic aneurism. She was given fairly large doses of potassium iodid, and within two weeks she had developed a deep blue line on the gums and a double wrist drop and she became rapidly emaciated and died, not from the aneurism, but from the lead. Oliver also reported at the Brussels Congress, in 1910, the case of a painter with double wrist drop in whose urine Bedson found considerable quantities of lead more than a year after the man had quit work. Oliver's most often quoted case of latent plumbism was in a woman who, when 19 years old, suffered from lead colic, blindness and paralysis, left work, recovered, married, and had several children. Seventeen years later, without having done any lead work during this interval, she had an attack of headache and ocular paralysis with diplopia, and was found to be eliminating lead in the urine. W. Gilman Thompson (21) also reports the case of a woman who had a marked lead line on the gums, stippling of the red blood cells, abdominal colic, and partial wrist drop, after an interval of five years free from exposure to lead. She had had a double wrist drop before.

I found a lead worker in the Cook County Hospital in Chicago suffering with typical colic and constipation lasting five days, and with stippling of the red cells. This was his third attack and came on ten months after he had last been in contact with lead. His second attack followed eight months' freedom from exposure to lead. Among the cases of encephalopathy described in Chapter 6 are those of two smelter workers from the ore hearth plants in southwestern Illinois, who developed encephalopathy several months after they had left the smelter. Teleky describes a case seen by Frankl-Hochwart in which latent plumbism became active after a fracture of the thigh. The patient, a woman fringe-knotter, worked for years handling silk thread which was weighted by means of lead. After her accident she developed a paresis of the radial and ulnar nerves.

Larzell's (22) case was in a man who while working as a foreman in a sheet lead works had so severe a colic that he almost died and was forced to give up his position. For sixteen years he had no contact with lead, but he was never as strong as before and suffered

more or less from "rheumatism." Three months before Larzell saw him he had lobar pneumonia and as the lung was slow in clearing up his physician gave him iodid of potassium, whereupon a typical foot drop developed.

An interesting side-light on the effect of changes in metabolism on the absorption of stored lead is furnished by Shufflebotham (23), in an article on the influence of military training on certain members of the British Expeditionary Force who came from North Staffordshire. In this contingent, between August, 1914, and the early spring of 1915, fourteen cases of lead poisoning developed, with anemia, constipation, headache, nausea, colic in twelve, neuritis of the arms in one. The men were all lead workers, ten of them potters, three painters, one a plumber. Only three had ever had such an attack before and in all the onset came on in three to seven weeks after the beginning of military training. Shufflebotham believes that the drilling increased metabolism and released compounds previously locked up in the organs and muscles.

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QUANTITY

Various data have been used in the effort to calculate the amount of lead which, ingested daily over a long period, may be capable of causing plumbism. Facts have been gathered with regard to several mass poisonings from drinking contaminated water, the most famous instance of which occurred at the Chateau de Claremont, where out of 24 persons 13 were poisoned in a short time by drinking water with about 65 mg. of lead to four liters, or 16.5 mg. per liter. More interesting, because more insidious and long drawn out, was the poisoning of nuns in a convent near Lyons which was discovered by Lacour after three had died and when twelve were still living and seriously affected with anemia, palsies, colic, and one had progressive paralysis and muscular atrophy. These nuns had drunk only water for years. The water was found to contain 2.7 mg. per liter and inquiry showed that there had been a change in the water supply ten years before which led to this contamination. All of the nuns in the convent were poisoned except two who had been there for only five months and one year, respectively.

An interesting account of self-experimentation in lead poisoning is to be found in early American medical literature. A young physician, Thomas R. P. Spence, of Accomac County, Virginia, on July 23rd, 1805, wrote a letter to John Redmond Coxe, M.D., the editor of the *Philadelphia Medical Museum*, which was published in the second volume of the 1806 issue. Spence tells of his personal experience with the use of sugar of lead in epilepsy. He had had epileptic seizures since his 23d year, that is, for the two previous years. He had treated himself unsuccessfully with bleeding until he was considerably reduced in weight, and then with cuprum ammoniacum, but at every full moon and change of the moon he would be subject to fullness in the head or headaches. Following

the advice of Doctors Rush, Wistar, and Church, of Philadelphia, he continued the above treatment and also took mercury, zinc, and lead. The mercury had a good effect provided he kept up a considerable ptyalism, which he did for seven months with two attacks of actual salivation. Bleeding was practiced regularly once a month. He had only four fits between May 27th and December 4th. By September he was so much reduced by this regimen that he left it off for cold shower baths, but he had two attacks and resumed the mercury. Dr. Rush then told him that he had good results in children with sugar of lead, though he had had little success with it in adults. Spence began to take it in quarter grain doses three times a day, increasing in one week to one grain, then after two more weeks to eight grains twice a day, and he continued this for three or four weeks, with "happy effect on the fits." He describes his condition at the end as follows: Costiveness, sponginess of gums with dark livid appearance around the incisors, fetid breath, mouth not sore although teeth were loose, a much greater increase of urine than under mercury, painful motion in the joints of the upper extremities, especially the elbows. He was then bled sixteen ounces and the following day lost accidentally eleven ounces more, whereupon his appetite left him and he went for three or four days with no food at all. Pain in the epigastrium then developed, extending down below the navel and also in the region of the liver and in the spine. This became excruciating and lasted for ten days. Less severe, but distinct, pain continued for six weeks, extending to the legs so that he could not stand. He had a slow convalescence, but for seven months he was quite free from epileptic fits. He hazards the suggestion that the good effect of the lead came from its "contracting the stomach and thereby preventing plethora"; for after this attack of colic he could never eat much without a sense of fullness in the stomach.

Schmidt (1) had the opportunity to study a case of slow poisoning which developed after years of drinking water with a relatively large amount of lead and he believes that the danger from this source has been exaggerated. His patient drank daily two and a half liters (!) of water containing 2.9 mg. of lead per liter, which means a daily dose of 7.25 mg.; yet it was two years before she felt the first symptoms of illness and two and a half years more before Schmidt saw her in a condition of pronounced plumbism, with colics, palsies, cachexia and a lead line. Schmidt estimates that she had had 5.3 gm. before the effect was felt at all and 12.6 gm. before the lead had done its full work.

Brouardel (2) used to emphasize in his lectures on industrial plumbism the importance of time in the production of lead poisoning. He said that in the middle of the last century it was customary to treat dysentery with carbonate of lead and that in the hospital

of La Pitié he saw 300 or even 800 mg. given for several days without any bad reaction; yet if the same patient should absorb 800 mg. in one year instead of in eight days, he would get lead palsy. "One must not conclude that the gravity of the danger depends on the size of the dose. I would almost say, with a little exaggeration, perhaps, that the reverse is true." He believed that the daily ingestion of as much as one centigram will cause poisoning. Teleky (3), puts the amount at a lower figure. A daily dose of anything over one milligram for several months may lead to symptoms of plumbism, while Brouardel's dose, one centigram, would produce acute symptoms in a few weeks.

The most satisfactory calculations for those interested in industrial plumbism are Legge's (4), based on analyses made by Duckering of the lead content of the air in certain workshops—potteries, tinning shops, painting coaches, and railway cars, etc. Taking these figures of Duckering's (5), and the records of plumbism among the employees of the given establishments, the length of exposure and the character of the plumbism that appears among them, he is able to make a fairly exact statement of the quantity of lead which is to be regarded as dangerous. He concludes that two milligrams per day is the lowest dose which, when inhaled as dust or fumes, may, in the course of years, set up lead poisoning. If the working day is eight hours—as it almost always is in British industry—this would mean about 5 mg. of lead to 10 cubic meters of air; for a man breathes about 600 cubic centimeters 16 times a minute, or 4,608 liters in eight hours. If there is no more lead in the air than this, encephalopathies and palsies will not occur, and colics rarely.

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CHAPTER 4

COLIC. ARTHRITIS

COLIC

Lead Colic.—The clinical course of a typical case of lead colic begins with more or less obstinate constipation which increases and culminates in an attack of intense, agonizing pain. This is usually spasmodic and during a paroxysm the exploring finger in the rectum can often detect alternations of violent contractions and slight relaxations. It is on this fact that the therapeutic use of belladonna, hyoseyamus and opium is based. The pain may be great enough to cause collapse, even delirium, with evidence of great suffering. In the early days (before 1912), it was not difficult to secure histories of white lead workers who had been picked up in the street by the police, helpless with lead colic. Sometimes there is no warning at all before an attack, but usually it is preceded by several days of discomfort, if not of pain. An Italian, employed in a Chicago white lead works, was seized with a pain so sudden and severe that he thought someone must have struck him in the abdomen, and he had no feeling of illness before.

The pain is referred to the umbilical region, and the patient doubles up or falls to the ground, pressing both hands over his rigid, retracted abdomen. In bed he is likely to lie on his face and pressure usually relieves the pain, except in neurasthenics, who often complain of exquisite tenderness over the abdomen, a symptom which may obscure the diagnosis; for many lead workers are neurasthenic. The pulse is decidedly slowed, small, with increased tension; the blood pressure during the paroxysm is raised, but falls as the pain dies down. There may be complete suppression of urine during the attack and the first urine passed after it may contain urobilin, hematoporphyrin, and even albumin and casts. The respirations are rapid and labored. Constipation is a marked feature in all but exceptional cases, about 3 per cent; nausea is common; actual vomiting, not so common; thirst is a very characteristic feature, as is the absence of sweat, even during the most agonizing pain; and there is a striking pallor from contraction of the surface vessels of the face. In France, Bernard (1) and others have distinguished a form of lead colic characterized by paralysis of the intestines and by meteorism, instead of by contractions, and Walko (2) says that the intestinal musculature in lead colic may be actually atonic. Finally there may be lancinating pains in the

limbs. The duration of this acute stage is usually more than twenty-four hours, although in light cases it may last only a few hours. There may be recurring attacks of intense pain with remissions for more than a week.

Walko studied the course of 43 cases of acute gastric plumbism in a hospital in Prague. He concludes that functional disturbances of the stomach appear very early in the course of poisoning, severe symptoms occurring after three or four weeks' exposure in men working in lead dust. There is a reduction or stoppage of acid and of secretion ferments, and a disturbance of the motility of the stomach, which last is at first greatly exaggerated, then reduced. The symptoms first observed are loss of appetite, metallic taste, nausea, vomiting, constipation, pain in the region of the umbilicus, which was typical colic in only one-third of the cases. The gastric juice collected after a test meal is small in quantity, lacking acid and ferments, although pro-ferments are present in all but very severe cases. The pain and disturbed digestion are probably caused by pyloric spasm, but later on there is atony of the gastric walls. In several cases carcinoma of the stomach was suspected, because of the presence of blood and lactic acid in the stomach contents and the profound anemia and cachexia. In others, the picture was that of gastritis anacida, or mucosa. The diagnosis was made by the rapid onset of the disease in a previously healthy man, the history of occupation, and the discovery of a lead line and of stippled red cells.

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ARTHRITIS

Arthralgia is one of the four manifestations of plumbism described by Tanquerel (1), the other three being colic, palsy, and encephalopathy. In his cases, it was next to colic the most common form, occurring in 755, and in 201 cases it was the only symptom; in the others it was associated with one or more of the other three forms. Usually a man susceptible to colic is also susceptible to arthralgia, but red lead makers—roasting oxids in the furnace—are more susceptible to arthralgia than to colic. In 463 cases of lead poisoning in red lead men, 400 had arthralgia, 63 colic. The prodromata of arthralgia are usually numbness and lassitude in the limbs: in 205 of the 755 cases, colic preceded an attack; in five, palsy; and in one, encephalopathy. The attack is very likely to come on at night, is most often localized in the legs, then in the arms and shoulders, then in chest walls, back and head.

These are Tanquerel's figures: 485, lower limbs only; 88 upper limbs; 108 upper and lower; 35 upper, lower and trunk; 18 thighs; 9 head; 5 chest walls; 4 back or neck; 3 head. Pain is most often "in the course of flexion," *i.e.*, along the posterior aspect of the thigh, the calf of the leg, and the sole of the foot, the arm-pit, anterior arm, fold of the elbow, palms of the hands. The pain affects the larger joints; the small usually escape. The pain is most often in the lumbar region of the back. It may be described as like a painful electric shock, or boring, or stabbing. Paresthesias, formication, numbness, and cold or heat may accompany it. It comes on in paroxysms which may be started by cold or by motion. Slow, gentle pressure relieves the pain; deep pressure increases it. The muscles cramp and may be felt and sometimes even seen as hard balls. There may be no heat or swelling and the pain does not follow the whole course of a nerve trunk. In 75 per cent of Tanquerel's cases the pain was bilateral, but not equal on the two sides. The rapid amelioration under treatment helps in the diagnosis; other aids are the fact that pressure and motion are not as painful as in articular rheumatism, and that in neuralgia the pain and tenderness are felt along the whole nerve trunk and with recovery the whole trunk is clear, while lead arthralgia clears up in sections.

Less stress is laid on arthritic symptoms by modern writers than by Tanquerel, yet this form of saturnism is recognized if not carefully studied. "Rheumatic pains," myalgia, arthralgia, are noted as aiding in a diagnosis of lead poisoning in dubious cases. (See page 103.) The pain may be as cramping as colic. It is relieved by gentle pressure, and a serious disabling attack does not usually last more than a week, but may recur many times.

A Negro, 22 years old, employed in a small Chicago refinery, stirring, skimming, and pouring lead for something less than six months, was awakened one night with cramps in his legs, "jumping from leg to leg," then spreading to all the muscles of the body, but never in all at once. He could feel his muscles contract into hard knots. Colic followed this. Another Negro, a white lead worker, complained of a "slow, aching pain" down his right leg from the hip to the ankle and from the left hip to the knee, on the posterior aspect of the limb. In the upper part of both arms he felt an acute, sharp pain and the right shoulder was very painful on movement, the right forearm sore to the touch, and the middle and ring fingers dropped slightly on extension.

That lead can set up true gout was first asserted by Garrod (2), in 1854. Strümpell (3) (1911 edition) says that he has often seen lead gout in Erlangen and in Leipzig, but always in men, such as painters and compositors, who had been exposed for many years to slow poisoning. Lüthje (4), whose article is always quoted

in this connection, asserts that lead can set up true gout, and that the distinguishing features of this form of gout are the following: the youth of the victims, the rapid spread of the disease, the involvement of joints spared in ordinary gout, the great tendency to formation of tophi. According to Strümpell, the prognosis of saturnine gout is poor.

Garrod said that one-fourth of all the cases of gout in England were to be found in lead workers, but Oliver (5) found lead gout rare in the north of England. In the experience of the Johns Hopkins Hospital for twelve years, one-half of the lead cases were associated with gout (W. Gilman Thompson). Thompson (6), himself, saw only five out of sixty-four cases of plumbism associated with gout.

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CHAPTER 5

LEAD PALSY

THE palsy of lead poisoning is a progressive muscular atrophy, toxic amyotrophy, which may be of the pure atrophic type, usually localized and of slow development, rarely generalized, and rapidly progressive; or it may belong to the spastic, atrophic type of Charcot's amyotrophic lateral sclerosis (1). Five varieties are generally recognized, following the classification introduced by Mme. Dejerine-Klumpke (2).

First is the antibrachial type which involves the extensors of the wrist and fingers, with the supinator escaping. Second is the brachial type which involves the deltoid, biceps, brachialis anticus, and the long supinator; and this is sometimes called the scapulo-humeral form and may be primary or may follow the antibrachial. Third is the Aran-Duchenne type of amyotrophy, *i.e.*, a more or less rapid atrophy of the small muscles of the hand which begins in the thenar eminence, then involves the interosseous and hypothenar muscles with flattening of the hand, the "*main de singe*," and then, as atrophy progresses and the middle and nail fingers flex, the "*main en griffe*" results. The fourth type is the peroneal, which, according to Tanquerel, is the type seen in 13 cases to 100 cases of type one. This type of palsy attacks the extensors of the toes, the peroneal muscles, and sometimes the tibialis anticus; moreover it is also bilateral, symmetrical, and is attended with loss of tendinous reflexes. The fifth is the very rare laryngeal type described by Seiffert in 1884 and later by Morell Mackenzie, Stieglitz, de Schweinitz, and others.

The first is by far the most common type and is the one usually meant when the term lead palsy is used without qualification. In typical lead palsy the common extensor of the fingers is first attacked and when an attempt is made to extend the fingers, the middle and fourth having no extensor of their own, remain flexed. In the early stage, the man cannot with extended fingers flex the hand dorsally (or extend the wrist), and if he tries to do so the first phalanges of the fingers begin to bend. The same thing occurs if passive flexion is attempted with the hand supported; for the weakened extensors are not able to keep the fingers extended against the pull of the interosseous and lumbrical muscles which are not affected. On the other hand, if the patient doubles up his fist or

even flexes the fingers half way, the hand can be flexed dorsally (the wrist can be extended*). Gowers (3) explained that if the fingers are extended, dorsal flexion of the hand (extension of the wrist) must be accomplished by the long extensor of the fingers acting alone—and in typical lead palsy this is the very muscle affected,—but if the fingers are flexed, dorsal flexion of the hand is brought about by the action of the true wrist extensors. This test reveals a very early stage of palsy of the long finger extensors. With extended wrist (hand dorsally flexed), the fingers will flex, the two weakest, the middle and ring fingers, showing the effect most, the index least.

This is the "antibrachial type" of Dejerine-Klumpke, Remak's (4) "forearm type." The palsy is always symmetrical, although usually unequal in degree on the two sides. In right-handed men the right hand suffers most, in left-handed, the left. Injury to other muscles follows more or less rapidly. The extensors of the index, the little finger and the wrist may be affected, as are sometimes the triceps, and sometimes the biceps; but the long supinator usually escapes. As the interosseous muscles are supplied by the ulnar nerve they are not affected, the fingers can be approached, and if the basal phalanges are supported, the fingers can sometimes be extended. A characteristic feature is the relatively slight involvement of the thenar muscles and the escape of the interossei. The osteotendinous reflexes are abolished in the upper extremity. Electrical excitation of the palsied muscles shows functional disturbance; faradic irritability is impaired or lost; galvanic, less impaired; and very rarely there is a reaction of degeneration.† Atrophy appears early, especially in the muscles of the back of the forearm.

The curious localization of the lead palsies, especially the typical form known as painters' palsy which involves some but not all of the muscles supplied by the radial nerve, has interested pathologists for many years. In 1904, Edinger (6) promulgated his theory as to the localization of lead palsies, and in 1908 brought it out in more complete form. It is an application to lead poisoning of the reasoning by which he sought to account for the localization of the lesions in tabes. As Edinger himself recognized, others had already connected localization of lead palsy with over-use of certain muscles because of the perfectly obvious fact that the palsied muscles were usually functionally related, although supplied by different nerves. Remak in 1875, Moebius (7), in 1886, and Vierordt (8), in 1887, had all noted these facts. Edinger studied chiefly painters'

* It must be remembered that the wrist extensors cause dorsal flexion of the hand; the flexors, volar flexion.

† Teleky (5) saw one case of greatly exaggerated patellar reflex and spastic gait. He also saw patellar clonus in another case.

palsy, the typical form of lead palsy because the most widespread. Teleky (5), in the following year, added a very interesting contribution to Edinger's thesis, with an analysis of many cases of atypically localized palsies in men and women engaged in various occupations, making a close study of the motions required by the occupation and of the exact muscles involved in the palsy. He confirms Edinger's exhaustion theory unqualifiedly.

The following is a brief statement, condensed from the long discussions of these two authors, of the underlying reasons for the peculiar grouping of affected muscles in various forms of lead palsy, especially in that known as painters' palsy.

Typical painters' palsy is an involvement of the long extensor muscles of fingers and wrist with escape of the supinator (brachioradialis), and sometimes involvement of the long extensor of the thumb with escape of the long abductor, and rarely involvement of the thenar muscles of the hand. It is, therefore, a palsy of certain muscles supplied by the radial nerve, but not of the supinator, and usually not of the long abductor of the thumb. The localization is founded on function and not on a primary neuritis.

All fine work and heavy work which requires exactness makes demands on a high functional activity of the long extensors of the fingers, the extensors of the wrist, and the small muscles of fingers and thumb. The human arm, with its powerful musculature of elbow and powerful supinators, is formed for heavy, rough work, such as lifting, dragging, carrying; while the wrist and finger extensors are built to perform only the slight activity required of them in heavy work, and yet in all fine work they are the ones most called upon. Lead workers while sometimes engaged in coarse work must do fine work from time to time, and the majority of them, painters, printers, potters, molders, lead burners, plumbers, etc., do work of more or less precision all the time.

Teleky quotes the physiologists, Duchenne and DuBois-Reymond, to the effect that the power of muscles bears a direct relation to their bulk. Now the muscles of the forearm which have the greatest bulk and the greatest capacity for work ("Leistungsfähigkeit"), are the flexors and extensors of the arm, the supinators, and the flexors of the fingers. There is very little power in the long extensors of the fingers, which are no more bulky than the pronators and the intrinsic muscles of the hand, and which, in addition, suffer from the disadvantage of widely separated attachments. In the thumb the long abductor and the flexors are the most powerful; but as the thenar muscles have opposing functions, the difference between groups in the thumb is somewhat equalized and is not so great as in the fingers. In doing fine work the hand is always in pronation, never supinated, and the extensors of the wrist must be constantly used to overcome gravity, to hold the hand up, the flexed

hand being able to do little work because the flexors of the fingers can work properly only when the wrist is dorsally extended. The extensors of the wrist are therefore called into use to help the most powerful and most continually used muscles, the long flexors of the fingers. The flexors of the wrist are called into use, not in fine work, but in heavy work such as lifting, pulling, carrying, with the hand in full supination. Therefore, in fine work the activity of the extensors of the wrist is much more constant and exhausting than that of the flexors, and to this is added their task of overcoming the pull from the finger flexors; for when the fingers are flexed around some object, a paint brush or a tool which prevents further flexion, the pull of the finger flexors is exerted on the wrist joint and must be overcome. The long extensors of the fingers do act also as extensors of the wrist, but only by exerting force on the extended fingers, so that they cannot help much when an increased demand is made on the extensors of the wrist, and such a demand is constantly made in fine work.

When the hand is at rest the intrinsic muscles of the hand, the interossei and lumbricales, hold the first phalanges of the fingers a little flexed, overcoming the long extensors; while their extensor action on the middle and nail phalanges is overcome by the flexors, and they also hang a little flexed, the index and fifth finger less than the other two. Slight flexion seems to express normal muscle tonus, and the extensors' function seems to be to equalize the effect of the flexors.

Throughout the ages man has had to perform chiefly coarse heavy work, such as lifting, carrying, pulling, and heaving, and his muscular system is adapted to this. Such work calls upon the long finger flexors, the flexors of the arm and the supinators, in grasping, while the extensors have little to do. In fine work, on the other hand, the extensors are in continual use to offset the flexors and to adjust the finger movements, and they, with the small muscles of the hand, have only about one-quarter of the bulk of the flexors. The intrinsic muscles suffer less than the extensors from overuse, because, being shorter, their physical relation to their points of attachment is much more favorable. Old people who have led hard working lives always have their fingers in flexion, but this is not true of the old in the leisure class or in the class of skilled workers.

In typical lead palsy, therefore, the involvement of the long wrist and finger extensors is explained by their relative slenderness, their intrinsic weakness, and their relative over-use, while the escape of the supinator, innervated by the same radial nerve, is explained by its bulk and strength and the fact that functionally it belongs with the flexors and is not over-used in fine work. The escape of the small muscles of the hand or their late involvement is explained on the ground of their favorable position with reference to their

attachments and by the fact that they work partly in conjunction with the powerful flexors. The long flexor of the thumb is bulky and is not affected. The extensor, although it is feeble, is little if at all affected because it is helped by the powerful abductor; while the thenar muscles are affected by fine work because such work calls upon the opponens and the short flexor and short abductor. The extensors of the fingers suffer more than those of the wrists, but the index is not involved as much as the other fingers unless it has had to work harder than they; for it is stronger. The little finger, especially on the left hand, is also less affected, not because it is strong, but because it is so little used. In all advanced cases of this form of lead palsy the right thumb is involved less often than the left. Atrophy of the interossei is rare and usually involves only the first interosseous space.*

Mellon (9), in Warthin's laboratory at Ann Arbor, undertook to test the validity of Edinger's exhaustion theory. He worked on frogs because they are convenient for stimulation and the results of fatigue can be computed in a mechanical way. He used lead acetate in water and by stimulating the muscles indirectly, through electrical irritation of skin, he avoided direct injury to the muscle substance. He concluded that if small doses of lead are used by this method, one can obtain conclusive evidence of the validity of the "Aufbrauchtheorie," namely that fatigue is the main factor in the localization of lead palsy.

Moebius first pointed out the peculiar localization of the palsy in file makers, a finding which was confirmed even by his opponent, Bernhardt (10), although it is not as invariable or uncomplicated as he thought. The file cutter uses the hammer with his right hand and holds the chisel grasped firmly in his left, striking the metal which is embedded in a lump of lead. The muscles most affected by palsy are those of the left thumb, used in grasping the chisel. Teleky saw a similar kind of palsy in two women who polished lead stoppers for bottles, a complete palsy of the short adductor of the thumb, the opponens, and the outer bundle of the short flexor, partial paralysis of the finger extensors, of the long abductor of the thumb and of the short abductor. The work involved the use of the opposing and adducting muscles of the thumb.

Other striking instances of involvement of isolated muscles have been published. Thus, Lilienfeld (11) described a case of pure ulnar nerve palsy in a type polisher who drew the type over a file with a motion always toward the ulnar side. Teleky has seen palsy

* Ingenious and satisfactory as this theory seems to be, it still remains to be explained why fatigue should determine the localization of lead palsy and not of other toxic palsies which occur in industry, such, for instance, as the polyneuritis of arsenical poisoning, if the effect of lead is exerted on the spinal cord and nerve trunks. The idea that the muscle is the real seat of the degenerative action of lead will not down, in spite of all the arguments brought against it.

involving the index finger chiefly in a type finisher who held the individual letters between index and thumb while filing them smooth. Manouvrier (12) saw isolated palsy of the fourth and fifth fingers in a man who pressed lead capsules over the tops of bottles, always making the final pressure with these two fingers. Another interesting instance of curiously localized palsy is given by Teleky. A painter had partial palsy of the finger and hand extensors, inability to lift the arm, and difficulty in rotating it,—in other words, palsy of the lifters, the deltoid (axillary nerve), the supraspinatus (suprascapular nerve), the teres minor (axillary nerve), subscapular and teres major (subscapular nerve), and of the rotator of the shoulder, the serratus (long thoracic nerve). This is a striking instance of the grouping of muscles by function, and not by innervation. The man had been painting machinery with red lead and had had to lie on his back on the floor and paint over his head. His shoulder symptoms cleared up before the extensor palsy, and when he went back to his usual work the extensor palsy increased, but he had no further trouble with the shoulder muscles.

When the work performed is less precise and more varied, the localization of the palsy is more widespread. In glass kilnmen, Teleky found involvement of the upper arm, the thumbs, the supinators, and the tibialis anticus, and he says that Remak noted a similar grouping in potters. I found that the glass kilnmen in American potteries, whose work requires them to lift heavy saggars filled with glazed ware and to place them in the kilns, did not often suffer from wrist palsy but from palsy of the shoulders, which they called being "shoulder bound." Labbé (13) found two men with acute lead colic, anemia, and palsy, with atrophy of the muscles of the shoulders. They had been working in an electric accumulator (storage battery) factory, rubbing litharge paste into lead grids. Even painters may have involvement of the shoulder muscles. Teleky saw this in three out of fourteen cases of painters' palsy, and Edinger said that next to the muscles of the wrist and fingers those of the shoulders were most used in painting.

Bernhardt, in Nothnagel's Handbook, says that disease of the axillary nerve with palsy and atrophy of the deltoid muscle, producing inability to lift the arm, is sometimes seen as an isolated phenomenon in lead poisoning, but the disability is not complete because part of the deltoid is innervated by the anterior thoracic nerve, and in lifting the arm, the deltoid is assisted by the coracobrachial muscle.

Oliver (14), has seen a wide distribution of lead palsy, involving muscles of trunk, back and shoulders, which are painful on pressure. This may come on in acute plumbism, although palsy is typically a feature of the chronic form. Wasting is rapid. If the muscles of

the upper arm are involved, the supinator is also. Palsy of the Duchenne-Erb group of muscles, deltoid, biceps, brachialis anticus and supinator longus, is sometimes seen. The triceps escapes, and although the man cannot bend his arm, he can extend it.

Hall (15), who was in charge of the Mexicans employed in the great lead smelter at Aguascalientes, reported, in 1910, 55 cases of palsy, in only five of which was there a typical wrist drop, and these men were furnace tappers using a long metal rod to coax out the molten slag and matte. Twelve had ankle drop, five paralysis of the deltoid only, three paralysis of the supra- and infraspinati, and 30 the Duchenne-Erb type involving deltoid, biceps, and brachialis anticus.

According to Thomas (16), by 1904 there had been treated in the Johns Hopkins Hospital and neurological dispensary 31 cases of lead palsy, in 26 of which the arms were affected, in four arms and legs, and in one the right leg only, this last being in a painter who had worked all day in a squatting position. The 26 arm cases were divided into 18 with double wrist drop, seven with right wrist only, and one with left wrist only.

Tanquerel (17) described 112 cases of palsy with varied distribution, the largest number, 97, being in the upper extremities, while the lower extremities were affected in 15 cases. These 97 were divided as follows:

General, of upper extremities.....	5
Shoulder	7
Arm	1
Arm, forearm, wrist, fingers.....	4
Forearm, wrist, fingers.....	14
Wrist, fingers	26
Wrist	10
Fingers	30

The intercostal muscles were involved in two cases; the dorsal, pectoral and sterno-cleido-mastoid, in one; the abdominal, in five; sixteen had aphonia and 15 stammering; six had disturbance of sight and hearing. Among the 112 cases of motor paralysis there were only five with anesthesia. There were eight with arthralgia.

Legge, reviewing the cases of lead poisoning, notified in Great Britain during five years, 1904 to 1909, found that the palsies had the following distribution: both forearms, 496; right forearm, 101; left forearm, 36; fingers, 36; arms and legs, 74; legs only, 28; others, deltoid, muscles of speech, locomotor ataxia, general paralysis, 10. Chyzer (18), in his remarkable investigation of family lead poisoning in Hungarian villages where pottery making is a house industry, discovered no less than 996 cases. Of these, 114 had marked palsy, 89 of them radial palsy, first of the right

hand, then the left, and sometimes involving the supinators. Eight had ulnar palsy, claw hand. After the palsy of the hands had lasted some time there was in 30 per cent of the cases a gradual involvement of the upper arm. Palsy of the lower extremities was seen only one-tenth as often as hand palsy. It affected mostly the muscles innervated by the peroneal nerve, only once the tibial. He also saw facial palsy. Later, in a personal communication to Teleky (5), Chyzer stated that among 120 cases of palsy there were 14 of the lower extremities, in nine men, four children and one woman. The work of the potter includes turning the wheel by foot pressure. In Chyzer's cases there is a strikingly large proportion of palsy of the deltoid, and of the muscles innervated by the ulnar, and of the muscles of the legs,—a true palsy, not Remak's transient weakness.

In 1910 I came upon 22 cases of palsy among white lead workers, only five of whom had palsy of the wrists alone, 13 had both wrists and ankles affected, and four had loss of power in the legs alone. These men were unskilled laborers, making coarse movements, lifting heavy pots, shoveling, trucking, and dumping. In this connection I might mention the statement made to me by an observant superintendent of a white and red lead works, who was trying to convince me that in lead poisoning the lead passes through the skin. He said, "I have noticed that men who work in the lead with their hands get wrist drop, the men who carry loads on their shoulders get palsy of the shoulders, and the truckers who pass to and fro over the dusty floor barefoot or with worn out shoes get ankle drop."

A good illustration of Edinger's theory as to the localization of lead palsy was related to me by Dr. A. J. Boucek, of Pittsburgh. A man had been employed for ten years filling wooden kegs with white lead paint and had never shown any symptom of lead poisoning. Then the company he worked for began to use small iron pails instead of kegs. The man had always held the barrel-shaped kegs easily, with his hands placed flat against the sides just below the bulge, but the iron pails had smoothly slanting sides and he could only hold them by crooking the ends of his fingers over the projecting bottom edge. He found the work far more tiring than his old work had been, and after a few weeks he came to Dr. Boucek with a double wrist drop that lasted several months.

Typical lead palsy of the lower extremities, or "foot drop," affects the long and short peroneal muscles and the common extensors of the toes, but the tibialis anticus, which also is innervated by the peroneal, usually escapes. The foot hangs, cannot be extended, and abduction and adduction are weakened. The plantar flexors, supplied by the anterior tibial nerve, escape. On the other hand, Escherich and Variot (see Edinger (6)) have found in the lead palsies of children an involvement of the tibialis anticus greater

than that of the peronei. Chyzer found the peroneal muscles involved in thirteen cases, the anterior tibial in only one, and this seems to be the most common form, but the picture is not as characteristic as in palsy of the upper extremities. W. and E. Weber (19) have shown that the extensor muscles of the leg are much larger in men than all the other muscles of the lower extremity put together, and that among the flexors, the adductors and abductors, the *tibialis anticus* is the most powerful.

In cases of leg palsy, Remak distinguishes between a weakness of the legs with heightened patellar reflexes which he considers purely functional, often following colic, and a true degenerative lead palsy with normal reflexes.

Oliver calls attention to cases of chronic plumbism which simulate vascular syphilis with one-sided lesions, palsy of one hand, of one foot, of the external ocular muscles on one side or a limited loss of muscular power, and slight weakness in one limb. Such a result may follow a plumbic endarteritis of the minute vessels of the brain followed by degenerative changes of a very restricted extent.

Aside from these localized, usually symmetrical, palsies accompanied by atrophy but not by severe neuritic pains, a great variety of paralyses have been described in the course of lead poisoning by experienced observers. Dejerine-Klumpke described in 1882 multiple neuritis of plumbic origin. Oliver has seen a widely disseminated polyneuritis with severe pain and rapid atrophy, tremors of the muscles, and palsy of the muscles of speech and of swallowing. Putnam (20), Bechtold (21), and Oppenheim (22), all report cases of palsy resembling spastic spinal palsy, with lead in the urine. Eichhorst (23), of Zurich, described a case of spastic paralysis in a painter with undoubted plumbism (line, stippled red cells, lead in urine and feces, colic, palsy), and referred to some earlier cases reported by Frerichs, Bechtold, Escherich, and Weber; but the number of such cases is small. Eichhorst also quotes a case of Philipson's, of rapid ascending palsy, generalized and fatal. A similar case, also fatal in a sanitary ware enameler who scattered dry lead enamel over heated ware, was reported to me in 1910 by Dr. Stybr of Pittsburgh (see page 15).

Dejerine-Klumpke says that lead paralysis may simulate Duchenne's subacute spinal paralysis, that is, a febrile form of general palsy. According to Gowers, lead poisoning may cause a progressive muscular atrophy similar in localization and features to the usual form, but distinguished from it by the fact that it is not progressive when the exciting cause has ceased to act. Commenting on this statement, Collier (24) says that he himself has never seen nor was he able to find in the numerous records of the National Hospital for the Insane in London, any cases in which un-

doubted lead poisoning was followed by typical progressive muscular atrophy.

According to Oppenheim the typical toxic palsies are those of lead, arsenic, alcohol, and diphtheria. If the effect of lead and alcohol are combined there may be a very rapidly developing palsy, and this, even if alcohol is used in moderation. In such cases we are likely to find other nerves affected besides the arms. He saw a case of painful polyneuritis of legs and arms, apparently typical alcoholic neuritis, but when it cleared up there was left behind an extensor palsy of the hands.

Tanquerel said that palsy usually occurs only after the patient has worked a long time in lead and has suffered repeatedly from colic. He studied 112 cases of palsy, in 63 of which there was a history of colic, and in all but three of these the colic preceded the palsy. In 39 there was no colic. The length of exposure to lead in these cases was as follows: less than a month, six; a month to a year, 16; over one and under five years, 28; six to twelve years, 24; twelve to twenty years, 20; over twenty years, eight. The precursors of palsy are a feeling of heaviness in the limbs, cold and stiffness, especially in the morning, passing off when the man warms to his work. Then he notices that fatigue comes on easily, prematurely; his fingers are numb and powerless, his legs bend under the weight of his body, and pains in the joints may precede the palsy. In eight of Tanquerel's cases palsy followed an acute encephalopathy. Relapses without further exposure to lead are noted by Tanquerel, and he says that Marechal has observed many recurrences of lead palsy years after the patient had withdrawn from lead work. (See page 53.)

Lead palsy tends to improvement or even to complete recovery. Every physician with a large practice in a lead center has seen workmen who give a history of wrist or ankle drop which has cleared up, leaving no trace. Teleky has seen lead palsy disappear completely in eight to ten days. If long continued, however, and accompanied with decided atrophy, such a paralysis may be permanent and in that case contractures will appear from the action of the opposing muscles.

The proportion of cases of palsy among the total number of cases of plumbism is difficult to ascertain because official lists of "cases" such as we find usually published, may include every case of plumbism seen, regardless of the fact that the same case may have been seen at the last monthly medical inspection, or they may include each new attack or relapse as a new case. Tanquerel says that he saw 2171 cases of lead poisoning, but if the individual case histories are counted, the number falls to 1493. Of these, 112 had motor palsy, which would be 7.5 per cent. Teleky, as physician attached to the sickness insurance bureau of Vienna,

saw 1336 cases between 1905 and 1909, 40 of whom had palsy. He says, however, that if he had counted each time he saw a case of palsy he would have had 65, or if he only called each relapse a new case the number would be 53. His percentages, therefore, would be 2.99 or 3.97 or 4.87, according to the method of reporting adopted. He believes it accurate to count each new attack a new case and therefore chooses 3.97 per cent as his figure. The British rate, which is excessively high, must be explained on the ground of the long duration of palsy, which brings it about that the same patient is seen and notified again and again. Between 1900 and 1909 inclusive there were 6762 cases of plumbism notified in Great Britain and palsy was present in 21.1 per cent of the men and 15.3 of the women. The larger proportion of cases among men is shown also in Prendergast's (25) statistics gathered in the pottery region, based on 640 cases. Fifty-seven per cent of the men and 30 per cent of the women had palsy.

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CHAPTER 6

LEAD ENCEPHALOPATHY

TANQUEREL DES PLANCHES (1), first in 1836 gave the name of *encephalopathia saturnina* to all forms of cerebral involvement in lead poisoning, but retained Griselle's classification of three forms—delirious, comatose, and convulsive—to which he added a fourth, the commonest type of all, namely, a combination of these three. Tanquerel says that the most characteristic feature of cerebral plumbism is the great variety of its manifestations. "*L'encephalopathie est une névrose de l'encéphale, à physionomie si mobile que du matin au soir, du jour au lendemain, les symptômes que décèle son existence changent complètement d'aspect ou de forme.*" It is, however, the least common variety of lead poisoning, and among Tanquerel's 1217 cases of industrial plumbism only 72 had cerebral involvement. The warning symptoms are usually severe headache, dizziness, sleeplessness, bad dreams, hallucinations, or disturbances of vision. The delirious form is characterized by confusion, incoherence, sensory hallucinations, slight tremors, chiefly of arms and face, difficulty in walking, embarrassment of speech and often amaurosis. The comatose form occurs suddenly, often in the midst of apparently good health. There are several forms of the convulsive, partial preservation of consciousness being a distinctive feature of lead epilepsy.

In 1880, some fifty years after Tanquerel, Westphal (2), published a study of lead encephalopathy which is still authoritative. He adds to the varieties described by Tanquerel an apoplectic form but he says that even with this the field is not covered; for into the picture of saturnine encephalopathy come features of progressive general paralysis, of bulbar paralysis, of disseminated sclerosis and laryngeal paralysis, of choreic symptoms and hysterical functional disorders. All these Westphal includes under the term *encephalopathia saturnina*.

Westphal presents 13 carefully worked up cases. He could not place them in Tanquerel's classification because that is based on a single symptom only, while many cases are complicated, presenting not only an epileptiform seizure but symptoms pointing to focal lesions in the brain. In some of his cases there was no delirium, no coma, no convulsion, but marked psychic disturbances with or without signs of nuclear lesions. He prefers to divide his cases

into those with general cerebral involvement and those with focal lesions. Seven of the thirteen cases had psychic symptoms of greater or less severity, such as depression, fears, extreme anxiety, loss of memory, mental deterioration, drowsiness by day and insomnia by night. Practically all had headache and attacks of dizziness and sometimes the pain was localized, with tender spots. Most of them had muscular twitching and jerking and in five there were epileptiform seizures with loss of pupillary reaction, generalized convulsions, and loss of memory. In some cases there were vague prodromal symptoms, but no true aura epileptica, a fact which Tanquerel also had noted. In one case, the convulsions were evidently of uremic origin.

As for those cases with focal lesions, six had involvement of the optic nerve; three of the facial, involving the buccal branch on one side, while the ocular branches escaped; two of the auditory together with the glosso-pharyngeal; two had a one-sided involvement of the olfactory; and one had paralysis of the left abducens. He believed that injury to the vagus was responsible for the rapid pulse in three cases, in one of which respirations rose to forty per minute, but without air hunger and with negative findings in the lungs. There were also two cases of involvement of the inferior laryngeal nerve. The hypoglossal was the only cranial nerve to escape in this series of cases, but Remak had a case of paralysis of this nerve which he attributed to lead. Two cases of Westphal's series had the high grade hemianesthesia described by Charcot, extending to the mucous membranes of the affected side. There was one case of aphasia and one of typical hemiplegia following apoplexy.

The early work in England in this field was done chiefly by Oliver (3), and the literature published later than the end of the last century has added very little to the picture of lead encephalopathy which these earlier observers gave to us. Oliver says that an epileptiform seizure may come on with no warning symptoms of plumbism, although in some cases severe headache precedes the convulsion. Lead encephalopathy consists in epileptiform convulsions, lasting, it may be, only a few minutes, followed by returning consciousness, or delirium, or dullness and depression. Women are more liable to encephalopathy than men, and young girls are especially susceptible. An attack is usually preceded by pallor, headache, perhaps hysterical excitement, which is followed by a convulsion in which the young woman may die or from which she may pass into coma, terminated by death, or by return to consciousness with severe headache, mental clouding, partial or total blindness. From this stage she may pass into mania, transient or ending in permanent dementia; or she may recover with impairment of vision; or she may recover completely.

Oliver says that encephalopathy cannot always be explained as the

result of changes in the kidney; for it may occur without albuminuria. Nor can the presence of lead in the brain explain all cases. "The presence of structural changes in the liver places saturnine encephalopathy much on the same footing as those obscure forms of poisoning which occur in pregnancy and in syphilitic patients* undergoing salvarsan treatment. It is a secondary poisoning."

Goodhart (4), in 1883, described several cases of "saturnine lunacy" characterized by hallucinations and illusions which resembled those of delirium tremens. In one of Robertson's (5) cases, a girl of 14 years, a noisy delirium persisted for five weeks, with complete disorientation and involuntary evacuations. There was no initial convulsion, but only a gradually increasing mental disorder. She recovered her reason, but with impaired hearing and total blindness. In the United States it was Putnam (6) who first called the attention of the medical profession to symptoms of plumbism which pointed to chronic disease of brain and cord, but the cases which came under his observation were not industrial in origin.

Quensel (7), in 1902, made a thorough study of the cases of lead encephalopathy in Flechsig's clinic in Leipzig. His article contains also an admirable review of the literature up to that date. He finds nothing in the pathology of lead encephalopathies which is distinctive, nothing which may not be found in non-lead psychoses. He describes typical acute lead psychosis as a condition of confusion and clouded mentality with disconnected, fleeting, insane ideas, relatively few hallucinations of the senses, varying emotional moods, with intermittent attacks of excessive motor excitation alternating with symptoms of inhibition, and interrupted by sudden lapses into stupor. This corresponds to Tanquerel's picture of the "forme délirante." Speech disturbances occur (Tanquerel noted this in 15 cases), and the delirium passes into a stage of dementia, followed by recovery. This form has been called "mania transitoria," "délire ou manie aiguë," "maniacal delirium," etc. Quensel distinguishes from this last a form which is specially characterized by hallucinations, resembling delirium tremens, but without albuminuria or tremor, and sometimes complicated with epileptic seizures. Of course, if alcoholism is present, too, the picture is a mixed one; for both may set up a hallucinatory delirium.

He, therefore, distinguishes three clinical forms of acute lead psychosis: (1) lead mania, (2) hallucinatory delirium, (3) that produced by both alcohol and lead combined, and resembling delirium tremens. All may have epileptoid features, and indeed the epileptoid character of lead encephalopathy is its most distinctive property and makes up as clear a picture as delirium tremens does of alcoholism. The convulsion is usually partial, like an electric shock,

or, if general, it is of the same character, followed by rigidity of the limbs and trunk and complete unconsciousness, eyes open and immovable. As noted above, Tanquerel believed that in typical cases there is not complete loss of consciousness.

Elschnig (8) describes a case of lead encephalopathy which closely simulated brain tumor until the symptoms cleared up. There was vomiting, headache, dizziness, attacks of unconsciousness, loss of memory, disturbances of speech; and the eye ground presented the typical picture of choked disk, with total blindness in one eye, diminished vision in the other.

Quensel describes the chronic form of cerebral plumbism as a dementia paralytica, probably in some cases purely coincident with plumbism, in others with an unusual symptomatology because modified by plumbism, for instance with epileptiform attacks or with hemianesthesia. Some of these cases should be regarded as saturnine pseudoparalysis with maniacal attacks and remissions. In others, the condition is essentially a pronounced secondary mental weakness, following acute encephalopathy, while in still others the condition should be regarded as one of high grade mental deterioration and paralysis, which is really an accompaniment of the cachexia and marasmus of severe and fatal chronic plumbism. Sometimes a polyneuritis is added to the picture. Or neurasthenic symptoms may complicate it. There may be a combination of toxic psychosis,—depression, exaltation, slight delirium, loss of memory, etc., with organic lesions of the optic nerve. Even a genuine epilepsy can be called out by lead poisoning (Putnam (6), Hale White (9)), or a condition resembling epilepsy with furor (Robertson).

General progressive paralysis of the insane is a variety of chronic cerebral plumbism which English, French, German, and American clinicians have described. Oliver (10) says that saturnine pseudo-general paralysis is not alcoholic, or hereditary; it has a sudden onset, with delirium, hallucinations, or epileptiform convulsions. It often resembles delirium tremens in its terrors and ideas of persecution.* Later, there is weakness of the muscles and of the intellect and memory, and embarrassment of speech greater than in ordinary paralysis of the insane. There are tremors of lips and tongue, and sometimes of arms and legs. The tendency is toward amelioration, but death may be caused by apoplexy or may occur during a convulsion. The diagnosis of this pseudo-general paralysis is based on the sudden onset, accompanied by acute symptoms, the rapid course, involvement of speech, and tendency to improve. Margarot and Blanchard (11), of Montpelier, described a case of

* In Smyth's case of chronic plumbism with mental disorder, the symptoms were quite like those of alcoholic paranoia, delusions of persecution, rambling, excited talk, an attitude of persecution toward his wife, along with good general intelligence. (See *Jour. Indust. Hyg.*, 1923, 24, 5.)

general paralysis in a painter 45 years old, who had dementia with delusions of grandeur, hallucinations, and atrophy of peroneal muscles. There was no alcoholism, no lues, no trauma; it was a progressive general paralysis of plumbic origin.

H. M. Thomas (12), of Baltimore, gives the history of a case of general paralysis following lead encephalopathy in an enameler who, less than three weeks after beginning work, became delirious, then had increasing weakness, and finally complete paralysis with loss of reflexes from the shoulders down. At that date, 1904, Thomas could find only twelve cases of general paralysis from lead in the literature. Osler (13) lays stress upon the varied manifestation of saturnine arteriosclerosis. As a result of chronic hardening of vessels the patient may exhibit quite early all the complex and varied manifestations of neurasthenia. The high blood pressure causes headache, sometimes paroxysmal and like migraine, and with it goes vertigo. He also called attention to the transient paralyses which are not uncommon in chronic hardening of the cerebral vessels,—monoplegias, aphasia, hemiplegia, even paraplegia, coming on suddenly and passing off after a short time.* They are to be attributed probably to angiospasm. Sclerosis of these vessels may also cause epileptiform seizures; but the most usual effect is a progressive dementia, a gradual failure of mental powers from the slow progressive shutting off of the blood supply from the brain. Rupture of the rigid cerebral vessels, apoplexy, is far more common among lead workers than among the ordinary run of working men.

Westphal's uremic form, with arteriosclerosis, is one that doubtless often fails to be recognized as of plumbic origin. Herter and van Gieson (14) reported an instance of encephalopathy of purely uremic character, although the victim, a painter, was only 26 years old. He had atheromatous arteries and albuminuria, double wrist drop with atrophy of the muscles, and slight foot drop. He passed into a drowsy state followed by a low, muttering delirium; the urine contained casts, epithelial and granular; there was a low urea elimination and a high urea content in the blood. At autopsy the kidney was granular with evidence of an acute diffuse nephritis. Lead was found in the organs, in the spinal cord, and in the brain; but the amount in the brain was small, whereas the cord contained almost three times as much; and since the vessels at the base of the brain were normal and there were no cellular lesions or lesions in the cranial nerves, the authors conclude that the brain symptoms were uremic in origin.

The statistics presented by Robert Jones writing in Oliver's "Dangerous Trades," illustrate strikingly the influence of lead on the

* See Oliver, *Brit. Med.*, Jan., 1921, 2, 108.

insanity rate. In the London County Asylum in 1900 there were 35 insane men who had been lead workers, but according to the proportion of lead workers in the population from which the hospital patients were drawn there should have been but 18. The lead workers had, therefore, almost double their due amount of insanity.

Ilirsch (15) was apparently the first to describe in detail the so-called lead neurasthenia, giving the histories of seven cases. It is, he thinks, a very common condition, characterized by violent protracted headache, present in four of his cases; by morning vomiting, in three; by severe abdominal pain which is not typical colic; by depression, irritability, timidity, exaggerated knee jerk, tremors; but by no other somatic symptoms.

Oppenheim (16) also described a form of neurasthenia which he asserts is very common among metal workers, especially among those working in lead, but also among mercury and brass workers. There is a sense of pressure in the head, loss of memory, abnormal excitability, and sudden sense of exhaustion, depression of spirits, irritability, anxiety and fear, trembling, palpitation of the heart, general weakness, increased tendon reflexes, fibrillary twitchings, tendency to excessive sweating, rapid irritable heart. With these symptoms there is a certain degree of marasmus; change in the electrical excitability of the nerves; tenderness of muscles, rarely of nerve trunks; and hardening of arteries and veins, especially of the veins of the legs, which may stand out like cords. The prognosis as to recovery is always poor. Optic neuritis may develop finally. An injury to such a person is more likely to end seriously. For instance, he saw a sudden development of radial palsy in a painter who had simply stretched his arms out wide. In the etiology of neurasthenia, hysteria, and epilepsy, lead, carbon disulphid and carbon monoxid play a large part.

As for saturnine hysteria, Charcot insisted that not all cases of plumbism with hemianesthesia, partial blindness and loss of sense of taste and of smell, should be referred to cerebral disease; for one must always bear in mind the possibility of hysteria. In the Salpêtrière, he had seen instances of lead poisoning leading to severe forms of hysteria with hemianesthesia.

The involvement of the eye is a prominent feature of cerebral plumbism, and there are many reports in the literature of various forms of visual disturbances in lead poisoning. Curiously enough Tanquerel saw only 12 cases of lead amaurosis in all his 1217 cases. Ten of these 12 followed encephalopathy. He observed no palsy of the external muscles of the eye, nor were any of his cases of blindness permanent; all recovered in from four to six days. On the other hand, Westphal (2), says that among his 13 cases of encephalopathy no less than six had disturbances of vision. He gives the following details; concentric narrowing of the visual field,

with loss of color sense in one; typical hemianopsia in one; negative ophthalmoscopic findings in two; atrophy of the papilla in two; a bilateral optic neuritis in one; and an albuminuric retinitis in one.

Hirschberg (quoted by Westphal) said that it was not possible to distinguish strictly between the visual disturbances caused by kidney disease from those caused by other forms of plumbism; but Weber (17), Lebrecht (18), and Oliver all insisted that the two must be clearly separated, and Oliver claims often to have seen neuro-retinitis long before albuminuria set in. Galezowski (19), in 1877, described neuritis optica, with or without atrophy of the disk, coming on usually suddenly in both eyes, sometimes during colic, and sometimes after an epileptiform attack, or after other cerebral disturbance. He also saw laming of the ocular muscles.

Elschnig (8) reviewed the 88 cases of lead blindness reported up to 1898 and put on record the first case of typical bilateral hemianopsia, temporal, caused by lead. The most usual form is inflammation of the optic nerve with atrophy or neuroretinitis. Another form is albuminuric retinitis. There may be a lead poisoning with hysteria, showing itself in loss of color vision, concentric narrowing of the visual field. Or a choked disk may simulate a brain tumor as in a case seen by Elschnig in a painter 35 years old, with vomiting, headache, dizziness, unconscious attacks, loss of memory, and disturbed speech. There was typical passive congestion of the papilla, almost total blindness in one eye, and diminished vision in the other. It passed over, leaving a left temporal hemianopsia. In permanent blindness the anatomical changes are clear, but in temporary blindness the condition is probably caused by a contraction of the vessels of the retina, a localized ischemia, as Elschnig saw in one case.

Thirteen years later, in 1911, Williams (20) reviewed the subject of lead amblyopia which he says was described 300 years ago, in 1611, by Smetius, and two centuries later by Tanquerel. It is, however, very rare (see on the contrary, Prendergast, page 82). In 1905, Lewin and Gueillery (21) could find only 142 authentic and well-marked cases in the literature. Blindness may come on suddenly and may be complete in a few hours, may pass rapidly, may leave permanent effects, may progress slowly to complete blindness, or may improve slowly to complete recovery. In some of the transient cases no change in the eye grounds is seen; in others contracted vessels, or hyperemia of the disks with edema of the retina, have been seen, while in the slow form which results in permanent damage there may be either no visible change at all, or a marked neuritis, or an optic atrophy. The visual field is always contracted and there are scotomata for color and form.

Left homonymous hemianopsia followed an attack of agonizing colic, delirium, and coma in a brass worker whose case is reported

by Posey and Farr (22). The trouble cleared up after ten days. According to them, this is a rare form of eye disturbance in plumbism, only five cases occurring in Lewin and Gueillery's list. The first was reported by Vater in 1832, the second by Westphal in 1888, the third by Hertel in 1890, the fourth by Elschmig in 1898, and the fifth by Bihler in 1899. Hertel referred it to a lesion in the posterior part of the internal capsule, localized ischemia or hemorrhage; Elschmig found choked disks; Bihler, a negative picture which led him to attribute it to a neuritis of the left optic tract.

De Schweinitz's (23) classification of lead blindness includes five varieties: (1) transient, without ophthalmoscopic changes, anesthetic effect on retina and optic nerve; (2) permanent, with no changes or slight changes, due to retrobulbar neuritis (there may be a terminal optic neuritis in both these cases); (3) optic neuritis or neuroretinitis, caused primarily by lead or due secondarily to changes caused by lead in the brain or kidneys; (4) optic nerve atrophy, secondary to plumbic papillitis, or due to the primary effect of lead; (5) various types of retinitis, from plumbic nephritis or primary vasculitis, or perivasculitis. The transient form is probably due to ischemia from vascular spasm, the permanent, to the action of lead on the nerve and to changes in the vessels, sclerosis, with ischemia or hemorrhage. A rare form is hemianopsia, of which there are seven cases in the literature, distinguished by its permanence from the hysterical form, which latter, however, may also occur in lead poisoning. In 64 cases analyzed by de Schweinitz 13 had optic neuritis, 4 neuro-retinitis, and 17 atrophy of the optic nerve. De Schweinitz says there may also be ophthalmoplegia from lead poisoning, paralysis of the orbital muscles, due to disease of the nuclei of the third, fourth, and sixth cranial nerves, and Brose (24) reports an instance of this rare form of plumbism in a painter, which improved on administration of potassium iodid and magnesium sulphate, but revived when there was another exposure to lead.

Saturnine palsy of the ocular muscles was found sixteen times by Elschmig in his review of the literature up to 1898. Disturbances of the pupil and of accommodation were very rare. The prognosis in cases of palsy of the external muscles of the eye is always poor. E. M. Williams (25) reported two cases of lead poisoning with paralysis of the external muscles of the eye, bilateral ptosis, and partial paralysis of the internal and external rectus muscles.

Miller and King (26), of Philadelphia, published a report of an unusual form of lead encephalopathy in 1896, unusual in its origin and in the predominance of eye symptoms. The patient, a woman of 22 years, helped in her father's carpet factory and for some time before her illness had been handling strips of the selvage of

green window-shade material, which she wound into balls for rug weaving. The green was ordinary lead chromate paint. After two months of this work she began to suffer from headache, vertigo, anorexia and dimness of vision, increasing in intensity. She worked on for three months, then went to bed with exacerbation of her symptoms to which were added constipation and vomiting. At the end of eight weeks she had an epileptiform convulsion and when she recovered consciousness she was blind. There was a slight return of vision for a fortnight, then total blindness. At the Episcopal Hospital it was found that she was extremely anemic, and had not menstruated for six months, had edema of ankles and under the eyes, that a lead line was plainly to be seen over the molars though it was hardly perceptible over the incisors, that there was no paralysis, no colic, and finally that no albumin, sugar or casts, but an appreciable amount of lead, was contained in the urine. The pupils were wide, and there was in both eyes paralysis of the right external rectus, pronounced hemorrhagic neuro-retinitis, swollen disk.

Oliver emphasizes the influence of sex in the cerebral form of plumbism, especially in the acute form. Women, above all young girls, are far more liable to lead convulsions and blindness than men are. Prendergast collected the following statistics from the pottery region of North Staffordshire, based on the findings in 640 cases of plumbism:

	Lead Poisoning in Men	Lead Poisoning in Women
Proportion of cases with:		
Convulsions	15.0%	34.9%
Total Blindness	2.3%	7.7%
Partial Blindness	3.5%	10.2%

My own experience, which is not at all extensive, and which was gained in 1911 in the pottery districts of Trenton, New Jersey, and of East Liverpool and Zanesville, Ohio, tends to confirm the statements of the English experts. I discovered 14 cases of encephalopathy which had occurred recently. No less than 9 of these were in women, and the 3 fatal cases were all in women; yet the force employed in these potteries in lead work consisted of 1100 men and only 393 women.

An early article, written in 1880 by Rayner, Robertson, Savage, and Atkins (27), of Glasgow, emphasizes the difference in character of lead insanity in men and women. They saw ten cases of lead insanity, four in women, which were characterized by rapid onset, convulsions and delirium in all but one, and in partial or total blindness in all; and six in men which presented a quite different picture, a slowly developing insanity, which in one case was

quite like general paresis, in the others, characterized by a gradual increase of sensory hallucinations without delusions of persecutions and with persistence of hallucinations of sight.

Tanquerel said that he had never seen a case of acute encephalopathia saturnina in a person who had not been exposed to air contaminated with lead dust or emanations. Modern observations bear this out. Thus Legge and Goadby (28) give the following distribution in industry of 38 cases of encephalopathy among 264 persons who died in ten years' time with lead poisoning as the chief or contributory cause of death: manufacturers of white lead, 13 (also two cases of apoplexy); china and earthenware, 8 (also 14 cases of apoplexy); paints and color, 4; printing, 3; storage battery manufacturers, 2; plumbing and soldering, 2; coach making, 1 (also 5 cases of apoplexy); file cutting, 1 (also 2 cases of apoplexy); ship building, one (also one case of apoplexy); smelting metals and glass cutting, each one; other industries, one case of encephalopathy and one of apoplexy; painting in other industries, one case of apoplexy. During these same years, 1900 to 1909 inclusive, there were 6762 cases of lead poisoning reported in Great Britain. They included 38 encephalopathies, 19 cases of epilepsy, 24 of optic neuritis, 26 of cerebral hemorrhage, and 15 of mental depression.

W. Gilman Thompson (29) says that encephalopathy is certainly rare in American literature, and he has himself never seen a case which could not be accounted for by alcohol or by uremia or by both. The cases which are treated in the hospitals of New York come chiefly from the painter's trade and from trades handling metallic lead, where there is very exceptionally an exposure to excessive amounts of finely divided lead in the form of fumes from molten lead or dust from soluble lead compounds. In centers of lead smelting in the United States, lead encephalopathy is still found, and in some few places "lead fits" are common enough to be familiar to everyone. The same is true of the pottery and tile centers, and of the towns in which sanitary ware is enameled, and, to a lessening extent, of the cities where white lead and the oxids are produced.

In the course of some fourteen years I have been able to collect histories of 132 cases of lead encephalopathy from the following industries: lead smelting, 42; white lead and lead oxid production, 24; pottery and tiles, 17 (of whom 12 were women, 5 men); painting, 15; enameling hollow-ware, 10; making storage batteries, 7; dry color grinding, 3; mixing rubber with litharge, 3; one each from glass polishing, brass founding, making bearing metal, soldering tin cans, printing, making sublimed lead sulphate, and cleaning stencils which are used for lettering freight cars with white lead paint. The remaining four were described simply as "lead

workers," men brought unconscious to the hospital and dying without being able to give any information about themselves.

In only 59 of these 132 cases could I obtain details of the onset, character and sequelae of the attack; in the others there was only the bare statement of the occurrence of an epileptiform attack or of an acute mania in a lead worker, sometimes fatal, sometimes not; or of cerebral symptoms following employment with lead. Three were coroners' cases, with the simple diagnosis "lead encephalopathy."

Thirteen, or 22 per cent, of the 59 died, and 20 were at the time the report was secured or the patient seen, suffering from some form of mental disturbance. Colic is noted in 28 histories; abdominal pain without typical colic in 8; in 12 no mention is made of this symptom, but in 11 the statement is made that there was no history of colic, and no marked abdominal disturbance. Epileptiform convulsions, preceded by loss of consciousness, partial or complete, occurred usually in those persons who had been doing work exposing them to large quantities of lead dust or fumes, such as in the white lead industry, especially stack stripping and dry pan dumping; smelting, especially on the ore hearth; glazing and cleaning glaze from pottery and tiles; scattering lead enamel over heated hollow ware; mixing litharge with rubber. The form found in painters and in the one printer was quite different,—arteriosclerosis, with dementia; but one painter, who had sandpapered white lead paint in interior decoration for nine weeks and had inhaled the dust, had an attack of epileptiform convulsions and was comatose for 73 hours and disabled for three months.

Six times in these histories it is noted that the men had no warning of the attack at all, falling unconscious while at work. One was working in the dry-pan room of a white lead plant and although he had had colic several times before, he was apparently in good health when this attack seized him. The second had been glazing tiles for 15 years and had never noticed any symptoms of lead poisoning, with which he was quite familiar, until one day while at work he suddenly fell to the ground unconscious, had severe convulsions, and for a week was delirious and stuporous. The third was a Bohemian enameler of bath-tubs who had worked only 18 months at the trade and had had no symptoms of acute plumbism, though his health had suffered somewhat. One day while at the furnace he lost consciousness, lay in coma for four days, then became delirious, and then it was seen that palsy had developed involving both forearms and both ankles and affecting his speech. He improved somewhat during six months' treatment, but when he left for his home in Bohemia he was still partly paralyzed. The other three cases are described on page 86-ff.

In most cases the history shows that there were warning signs of some kind before the attack. Two men described an intense

pain in the head just before they lost consciousness, "as if a nail had been driven in," "as if something had blown up inside my brain." Both had started work in the morning feeling well. In other cases the warning, vague as it was, should have led to prompt attention and perhaps to the prevention of an attack. For instance, I found in the Cincinnati City Hospital a Negro who had been brought there unconscious from the street where he had fallen. He died the following day. Inquiry revealed the fact that he had been a white lead worker and that for several days the other men had noticed that he was "trembly and jerky," and on the day before his attack the doctor in charge of the plant had found him very nervous, "looking excited and wild-eyed," but had paid no attention to what in a white lead worker, especially a Negro, should have been taken as a warning of serious danger. Another Negro also, in white lead work, complained for several days of a feeling of weakness in the legs, and of fogginess before his eyes, but no attention was taken of it and he, too, had severe convulsions, not fatal, but followed by dimness of vision. Dizziness and faintness have preceded an epileptiform attack in the cases of several women pottery employees with whom I have talked, and some of the younger ones have had hysterical manifestations for some time, and then a sudden epileptic seizure.

In 14 cases there was delirium without convulsions, lasting in one instance three weeks, in another a fortnight. One enameler while at work at the furnace became suddenly wildly maniacal, shouting, singing and dancing. In a Negro white lead worker the delirium was accompanied by colic, headache, dizziness and obstinate vomiting, but when these symptoms subsided, hallucinations of sight persisted and he had to be sent to an insane asylum. Delirium from the agonizing pain was apparently responsible for the death of a young American enameler; for he took at one dose all the morphine tablets left by the doctor and died of morphine poisoning.

Often the patient was left with some impairment of mental powers, sometimes lasting only a few weeks, sometimes for months or for the rest of his life. Melancholy, depression, loss of memory, sluggishness, hallucinations of sight and hearing, are the forms most often noted. Nineteen of the 59 cases belong in this class. In others the acute encephalopathy seems to have been the exciting cause of an epilepsy which persists. An American smelting worker who had been on the feed floor of a blast furnace for three months had no history of epilepsy. He had an attack of colic with acute mania, and as the latter persisted for two weeks he was transferred to an insane asylum where he remained for three months, with hallucinations, hemiplegia and hemianesthesia. Since then, if he is subjected to any unusual strain, he has an epileptiform seizure.

A chronic type, with arteriosclerosis, pseudogeneral paralysis

and dementia, was seen nine times: in six painters, in an enameiler, in a dry color grinder, and in a printer. A typical history is that of a color grinder whom I saw in 1911 with Dr. Theodore Diller at St. Francis Hospital in Pittsburgh. He had had many attacks of colic and ten years before this date he had double wrist drop. In November, 1910, he fell to the ground unconscious and had a convulsion. Another convulsion, more violent, came in March, 1911, and a third, six weeks later. When I saw him in May, 1911, he presented a typical picture of general paralytic dementia with arteriosclerosis. Wassermann and Noguchi tests were negative. He died that summer, aged 57 years.

Finally, there is in this group of 58 encephalopathies one instance of the cachectic type, in a Hungarian, 36 years old, who had had three attacks of colic, vomiting, and headache during seven years' employment at paint grinding. I saw him in St. Francis Hospital in Pittsburgh, emaciated, his limbs soft and flabby, his muscles wasted, and with extreme weakness. His color was a dirty yellowish gray, his eyes were dull and expressionless, and he lay in an apathetic condition unless roused, when he would answer rationally but slowly and after an appreciable delay, then sinking back into indifference. His red cell count was 3,900,000 and there were many stippled cells and some normoblasts.

In two instances the attack of acute encephalopathy came on after an interval free from exposure to lead. One was in an American Scotch hearth smelter, who after being away from his work for about a month was seized with severe colic, and a delirium which lasted five days. The other was a Russian, doing odd jobs about a smelting plant till he developed palsy of wrists and ankles. While he was under treatment for this some weeks later he had a convulsion, followed by delirium, and then by mental confusion and dullness.

Three cases of lead encephalopathy were treated in the Boston Psychopathic Hospital * in 1923 and inasmuch as the histories of these cases are much more detailed than is true of the ordinary hospital cases it seems advisable to give them in condensed form here.

Case 1 was in a Negro, 34 years old, admitted March 21, 1923. He had worked in the mixing room of a rubber shoe factory, handling litharge for three years, and he had previously worked for two years in Hartford mixing rubber. While in Hartford he had had an attack of "meningitis" with headache and backache and delirium but no fever and no convulsions. Since then he had suffered from occasional severe headaches, although up to that time he had always been in good physical condition and had never been a drinker.

* I am indebted to Dr. C. Macfie Campbell for permission to use these histories.

Five weeks before entrance he was obliged to stop work because of bad headaches, attacks of dizziness, and feelings of weakness, weariness, and nervousness. He rested for two weeks, then went back, and that same night, just after taking a hot bath in the factory, he was seized with a convulsion, fell and hurt his eye and bit his tongue. The following morning he had another convulsion, or rather a series of attacks lasting for two hours, when he was quite out of his head and it took two men to hold him in bed. But there was no frothing at the mouth and he did not bite his tongue. His wife stated that he had been growing very forgetful for the past five weeks, that he said his mind was going. He was depressed and apathetic and would lie for hours not speaking unless he was spoken to.

On entering the hospital his gait was unsteady, there were tremors of tongue and fingers, a marked speech defect with slurring and transposing of syllables. There were no paralyses, pupils were equal, reacting to accommodation but not to light, reflexes were over-active,—otherwise examination was negative. He had a marked memory defect for recent and for remote events, especially for dates. The blood count was 4,116,000 reds, hemoglobin 50 per cent, differential white count normal. The red cells showed marked achromia, anisocytosis with macrocytes, poikilocytosis, polychromatophilia, and occasional stippled cells. The Wassermann reaction was negative.

On the day after admission the patient became violently excited and it took six men to get him into a wet pack, but in the intervals of such attacks he was gentle and co-operative and fairly well oriented, with no delusions or hallucinations. He was transferred to the Westborough State Hospital with a tentative diagnosis of general paralysis of the insane and lead poisoning. He died in less than twenty-four hours, with a "congestive seizure."

Case 2 was in a Negro, 25 years old, admitted April 26, 1923. In October, 1922, he went to work in the mixing room of the same rubber shoe factory where No. 1 was employed. Here he handled large quantities of litharge and sometimes worked overtime. He was not a drinking man. About Christmas time he began to suffer from indigestion and abdominal pain and obstinate constipation, none of which symptoms had ever troubled him before. Nine days before admission to the hospital, while changing his clothes in the factory, he suddenly lost the sight of his left eye and had paralysis of the left arm and leg. This passed over and he went back to work, but on the day of his admission, while working at his bench, he fell to the floor and after lying there a few minutes got up and was so violent that it took five men to hold him. In the hospital, lying in a wet pack, he was in a semistuporous delirium, moving his head back and forth with his eyes closed, frothing at the mouth.

He made no attempt to speak and it was not possible to tell if he understood what was said to him. His limbs moved convulsively sometimes and his breathing at times was stertorous. His pupils were equal, reacting to light; his reflexes, equal and active. There was a definite lead line on both gums. He held himself rigidly and the abdominal muscles were contracted. The urine examination on the third day revealed hyalin and granular casts and a trace of albumin. The red blood cell count was 2,624,000, hemoglobin 80 per cent, leucocytes 31,000 with the polynuclears forming 88 per cent; the red cells showed marked achromia, poikilocytosis, anisocytosis, and stippling. The Wassermann reaction was positive. He had repeated convulsive attacks while in the hospital with clonic contraction of arms and legs and jaws lasting several seconds, affecting the right arm and right leg and facial muscles of the right side and accompanied by grinding of teeth and frothing at the mouth. Later on the left side was also involved. He died during a convulsion at midnight of the fourth day.

The spinal fluid obtained by lumbar puncture had an increased cell content. The autopsy findings consisted in pulmonary edema, broncho-pneumonia, slight fatty change in the liver, an hour-glass stomach, the brain pale, slightly swollen, resilient, springing back on pressure, and local thickening of the dura and pia along the vessels over the surface, especially in the mid-vertex region.

Case 3 was in a white man, a Lithuanian 30 years old, brought to the hospital by the police as an insane epileptic whom they had found wandering about the streets and who showed confusion and dullness and difficulty in understanding questions.

He proved to be a rubber mixer in a factory where he had worked for ten years, up to six or seven weeks ago when he left because he felt ill. He was a habitual drinker and occasionally got intoxicated. According to his brother's account, a week before he entered the hospital, he had three "epileptic fits" in one day with clonic and tonic twitchings and frothing at the mouth and unconsciousness lasting fifteen minutes. After that he was noisy, confused and violent and had hallucinations.

Examination showed physical weakness, a double wrist drop with atrophy of the muscles of the forearms, overactive wrist jerks, coarse tremors of the muscles, and weakness of the muscles about the eyes. There was also weakness of the deltoids. The pupils were equal, reacting to light and accommodation. There was a lead line on the gums. The Wassermann reaction was negative, the spinal fluid, normal. The urine had a slight trace of albumin and hyaline casts. The red blood cell count was 3,836,000 with hemoglobin 75 per cent; the white cells numbered 14,500 with 66 per cent polynuclears, 28 per cent lymphocytes, 5 per cent large mononuclears. Forty-one

stippled red cells were found while counting 100 leucocytes, and also two normoblasts.

The patient was restless, confused, sometimes disturbed, combative and irritable, but he was coherent. He was not oriented to time or place or persons. His memory was poor, but not lost. He was anxious and fearful and had hallucinations of sight and smell. The spinal fluid was sent to Dr. Joseph Aub for examination and a considerable amount of lead was found. The patient was discharged January 23d much improved mentally and physically.

Several points stand out from these histories. In the first place, the severity of lead encephalopathy in Negroes; in the second place, the danger of neglecting symptoms of lead poisoning and of permitting workmen, especially Negroes,* to continue in lead work after such symptoms have appeared; in the third place, the lack of knowledge on the part of most physicians of the different industrial processes which involve exposure to lead, without which knowledge a correct diagnosis of the early symptoms of lead poisoning will almost never be made.

Another detailed history which has come into my hands is that of a Polish laborer, 30 years old, of strong build and healthy, who at the time of his employment was apparently free from any physical defects. In 1917 he went to work for a company making bearing metal† and continued with them until 1921 when he left because he was suffering from stomach trouble and obstinate constipation and was losing weight and strength. He worked for about a year in a meat packing plant, and then, having regained his health, he returned in June, 1922, to the bearing metal company. His old trouble returned, he began to lose weight, to suffer from indigestion and from constipation, and in December he had an acute attack of colic and was ill from the 11th to the 26th. A second attack incapacitated him from January 2d to 15th. His weight had gone down from 205 to 149 lbs.; he was easily wearied and was often drowsy. Constipation was continually troubling him, and sometimes it was almost impossible to overcome. The company physician put him on outdoor work, saying that he was suffering from lead poisoning.

On February 10th he went to work at seven in the morning, apparently in his usual condition, but an hour later he was found lying unconscious on the ground. He came to himself in twenty minutes and the examining doctor, finding nothing wrong, let him go back to work. At 10:30 a fire broke out in a shed and this man climbed to the roof to help put it out. While there he suddenly crumpled up and fell in a heap on the roof in convulsions. He was unconscious when the doctor saw him and continued so, with

* See p. 7, on susceptibility of Negroes to lead.

† Bearing metals are alloys of lead, antimony, copper, zinc.

recurrent attacks of convulsions which were not epileptoid in character. The convulsions were usually brought on by some disturbance made in the course of examination or treatment, such as lumbar puncture, and though tonic with occasional clonic spasms, they were not accompanied by tongue biting, the mouth was usually open, there was no involuntary defecation, and rarely urination. The seizure lasted three or four minutes. During the attack the pulse rate (which usually was 75 to 90) would drop to 20, and the diastolic blood pressure almost to zero, although the systolic pressure maintained itself fairly uniformly at 140. After the attack there would be a period of prostration with profuse sweating and profound coma.

The pupils were contracted and sluggish to light, but there were no visible changes in the fundus. Deep reflexes were accentuated, especially the patellar and tendo Achillis. A marked ankle clonus and a marked Babinski could be elicited on both sides. The superficial reflexes were normal. The abdomen was retracted and scaphoid, but meningeal symptoms were lacking, there was no retraction or rigidity of neck or spine, Kernig's sign was absent, and spinal puncture yielded a clear fluid which came out under slightly increased pressure, but was sterile and without excess of cellular elements. Voluntary movements excluded any possibility of paralysis. The rectal temperature on entrance to the hospital—on the day of his seizure—was 99.2, and it ranged from 99 to 102.5. The urine contained a trace of albumin, but no casts; large numbers of leucin and tyrosin crystals were present. The blood count was: reds, 3,850,000; whites, 14,600, with slight increase of polymorphonuclears. Microscopically the blood showed many abnormal reds, macrocytes and microcytes, poikilocytes, polychromatophilic cells, and marked stippling.

For 48 hours after entering the hospital the patient was under restraint in bed because of his extreme restlessness; then this died down and he sank into deep coma from which it was impossible to rouse him, so that he had to be fed through a stomach tube. There was involuntary urination, but no incontinence. The convulsive attacks continued with lessening frequency and severity for five days, always being traceable to some irritation or disturbance. His stupor lasted eleven days, when slowly intervals of semi-clarity appeared; but his mind was not really clear till the nineteenth day after the accident, when he first began to ask what had happened to him. There were four days of great improvement, his appetite was ravenous, he was allowed to get up and take a bath alone, his diastolic pressure rose to 60, his red count was a little over four million, and his white count was 9,800.

Then, on March 3d, he showed novel symptoms: he became suspicious and fearful, distrusted the nurses, thought someone was

trying to steal his clothes, was restless and wanted to leave the hospital. After a sleepless night he presented the symptoms of an acute psychosis,—great restlessness and excitement, and hallucinations of sight and hearing, all with persecutory content; and he became so unmanageable that he had to be removed to the Psychopathic Hospital. The last report, March 23d, states that his hallucinations have disappeared, and that he is quiet; but his mentality is sluggish and he is slow in understanding a question and in framing an answer.

The literature on lead meningitis is almost entirely French. There is one Italian article by Preti (30) and the article by Plate (31) in 1913 is, so far as I can discover, the only one in German. Renault (32) spoke of lead meningitis in 1875, but it is to Mosny and his pupils, especially, that we are indebted for our knowledge of this form of plumbism. Mosny and Malloizel (33) discovered by chance that in lead colic, even when there were no nervous symptoms, the spinal fluid in man showed marked changes, and they adopted as a routine measure in all cases of lead poisoning the examination of the fluid withdrawn by lumbar puncture. There was always a marked increase of pressure and often a very decided increase in the albumin and in the cellular elements, which were almost always lymphocytes. They hold that these meningitic changes are chronic in character, with acute exacerbation at the time of the colic, but they occur only in persons exposed to massive doses of lead, not in old saturnins. The meningitis of saturnism is characteristically subacute, abortive, at times latent, and at times explosive in character. At autopsy there is an intense congestion of the meninges and an exaggerated secretion of fluid, which contains blood and lymphocytes. The meningitis may take a bulbar form (Braillon and Bax (34)), or involve the cranial nerves (Frédéric (35)).

Loeper and Pinard (36) reported a case in a maker of storage batteries, employed for 10 months, during five of which he suffered from headache. This case was one of lead encephalopathy complicated with symptoms of meningitic irritation. The man had several epileptiform attacks, then agonizing colic with an effortless vomiting, headache, delirium, opisthotonos, Kernig's sign. The attack ended in profound sleep and he awoke with no memory of it. Here lumbar puncture yielded a fluid with 40 leucocytes to the microscopic field. The diagnosis of lead was strengthened by the presence of the lead line and by the blood examination, which showed stippling of the reds, low hemoglobin, 65 per cent, and 4,992,000 reds, 9,600 whites.

In one case described by Mosny and Hervier (37) the man was blind for three months, when his sight gradually returned. It was not possible to find any lesions in the fundus, the pupillary reflexes

were normal, the blindness could not have been caused by hypertension; for it did not yield to the administration of the nitrites. This was a complicated case, with symptoms of meningitis at first, severe headache, partial coma, temperature of 41.5° C., Kernig's sign, and characteristic findings in the spinal fluid. Then attacks of Jacksonian epilepsy developed, affecting the left arm, and for two months the man had intermittent attacks of delirium and apathy. The blindness the authors believed to be hysterical in character, and this belief was strengthened by the fact that as the man recovered he claimed to be able to see far objects, but not near ones, and to recognize certain colors and not others.

Preti, of Italy, contributed a case with meningitic symptoms in a painter who, during his ninth attack of colic, developed paresis of the legs which lasted two weeks. Ten days later he had fever, intense headache, pain in the back of the neck, Cheyne-Stokes respiration, and unconsciousness. The spinal fluid, which was sterile, came out under high pressure and lead was recovered from it. He regained consciousness immediately after lumbar puncture and in a week was well.

Boveri (38) finds that in acute plumbism the meningeal reaction consists in augmented pressure, augmented albumin, and increased leucocytes.

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CHAPTER 7

DIAGNOSIS

THE diagnosis of lead poisoning cannot be based upon any one clinical finding, nor upon an entirely typical symptom complex but rather must depend upon a more or less varying group of subjective symptoms together with one or more objective signs, occurring in a person whose occupation is known to involve exposure to lead. The history of exposure is of enormous value. Although the descriptions of chronic lead poisoning as usually made read very well, anyone with a wide experience knows that the so-called typical case is a rarity. A well-marked chronic case without acute exacerbations would probably be characterized by several of the following symptoms: constipation, abdominal pain, or heaviness and discomfort referred to the region of the stomach, evidence of indigestion with eructation of gas, foul taste especially in the morning, loss of appetite especially for breakfast, headache, insomnia or disturbed sleep, loss of strength especially in the muscles most used, loss of weight, slight tremors of tongue, lips, and fingers. There is often a dirty yellowish gray pallor, which is easily recognized by an experienced lead worker, and a lead line on the gums. If in the course of such a train of symptoms there occurs an acute colic or a marked weakening of the extensors of fingers and wrist, the picture is indubitably clear.

The Burtonian line, or so-called lead line, appears as a bluish black stippling along the margin of the teeth, clearest usually along the lower incisors. In the early stage when the stippling is very fine a hand lens should be used to detect it, and it is a help to slip a sheet of stiff white paper between the edge of the gum and the teeth. The lead line is an evidence not of lead poisoning but of the absorption and excretion of lead. Tanquerel thought it only a deposit of black sulphid on the surface of the gums, and according to Blum (1), Fogge, an Englishman, in 1876 first showed that it was made up of small particles lying about the smallest vessels. These particles of lead penetrate through the capillaries of the mucous membrane of the mouth and, coming in contact with sulphuretted hydrogen formed by decaying food, are changed to the black sulphid. A mouth with only sound teeth, which is kept very clean, will probably show no lead line. On the other hand it may be impossible to find the lead line in a very foul mouth with excessive pyorrhea because of the constant sloughing of the surface cells. I

examined six enamelers of sanitary ware who all showed symptoms of chronic lead poisoning, but in all the mouth was in a very bad condition, with inflammation, pockets of pus, caries, and loss of teeth, and the lead line showed either slightly or not at all. It is best seen in men with a slight degree of gingivitis whose mouths are not overcleanly. American printers do not often show it. Knieren (2) says that about half of the 600-odd cases of chronic plumbism seen in the Leipzig clinic, the majority of whom were printers, showed a lead line, but among 200 working printers examined by Palmer and Ellis (3) in Boston and Chicago, only two showed it, although 18 had chronic plumbism.

Linenthal (4) has seen instances of undoubted lead poisoning where there was no sign of the blue line, and considers that the line is "extremely rare when the gums are in a healthy condition and when the teeth are cared for," and this is also the opinion of Harris (5) who found the lead line in less than 14 per cent of the active cases of plumbism among New York painters. On the other hand, Marvin Shie (6) reports that 90 per cent of all his lead workers (chiefly pottery glazers and metallurgists) had well-marked lead lines not invariably associated with inflamed and defective teeth. Schoenfeld (7) found a clearly defined lead line in only 48 out of 126 cases, and in 44 cases there was no sign of it. It was never seen in men who had lost their teeth.

Oliver (8) calls attention to a sign which is fairly common in the mouths of lead workers, a bluish black spot on the lining of the cheek opposite a carious tooth. Legge and Goadby (9) saw a lead worker who had his teeth coated with foul tartar and although he showed no typical lead line along the margin of the gums, he had from time to time spots of pigmentation on the internal surface of both cheeks in the region of the buccal papillae of the parotid duct. Knieren (2) described grayish black spots on the inner surfaces of the cheeks running in a line just opposite the upper and lower teeth.

The presence of the lead line is always a valuable aid in diagnosis, and although it should not be regarded as evidence of lead poisoning, in the absence of symptoms,* nevertheless it shows that lead is being absorbed and British factory inspectors follow the practice of keeping workers who have a lead line under observation. It is evident that if the line be present the worker is absorbing lead, although for the moment perhaps not beyond his capacity to excrete it, but it is impossible to say when he may pass beyond the limits of his tolerance.

In the effort to find some swift and sure method of diagnosis,

* Wade Wright saw a Burtonian line (sulphid of mercury ?) in four out of one hundred felt hatters who were exposed to mercury but not to lead. (See page 273.)

various clinical tests have been suggested, such as the detection of lead in urine and feces and the discovery in the blood of stippled red cells or of an increase in mononuclear leucocytes. Both blood and urine examinations have been found to be of great value in the hands of some observers and of dubious value in the hands of others.

The discrepancies are so wide in the findings of trustworthy students that they can only be explained on the ground of differences in technique.

One of the earliest to make the diagnosis of lead poisoning in obscure cases by means of detection of lead in the urine was J. J. Putnam (10) of Boston, who in 1883 presented three cases of organic disease of the spinal cord, one simulating lateral sclerosis, or a transient form of poliomyelitis anterior, and two with a more diffused form of myelitis and cerebral neuroses. These all had lead in the urine. Putnam found lead in the urine of eight cases of nervous diseases, none of whom had a lead line, or colic, or emaciation, or discoloration of the skin, or characteristically localized palsy, or typical cerebral symptoms. He referred also to a case shown in 1881 by F. Minot to the Medical Improvement Society of Boston, a man with some symptoms of lateral sclerosis in whose urine lead was twice found.

Oliver, who has never been able to get much help from the blood examination in diagnosing lead poisoning, finds the test for lead in the urine of decided value. Judd (11) reported a very interesting case in which the diagnosis was made only after lead was discovered in the urine. The victim was a young plumber with no lead line, no history of colic or constipation or alcoholism who died after three days of convulsions and delirium. Recently, McDonald and McCusker (2) have published the histories of 12 cases with obscure symptoms, 4 of them industrial, in which the diagnosis was based on the discovery of lead in the urine. Seiffert (13), who examined the urine of 73 cases, found lead only eleven times, that is in 15 per cent, and von Jakseh (14) says that it fails in just those cases which are most difficult, the chronic cases with an obscure train of symptoms.

Albumin is not often found in the urine in chronic lead poisoning but the presence of hematoporphyrin is noted by some as being of great significance. Deroide and Lecompt (15) were the first to notice this phenomenon, in white lead workers in Lille. They found it in the urine of 12 out of 13 patients. Two Dutch clinicians, van Emden and Kleerekoper (16), found in the urine of lead poisoned persons quantities of hematoporphyrin * so constantly

* According to recent studies by Schumm (17), the spectroscopic and physical properties of the porphyrin excreted in the urine in cases of lead poisoning show that it has the characteristics of fecal porphyrin and not of true urinary porphyrin, such as is found in poisoning from veronal. (See also Hans Fischer (18).)

in excess of the normal as to lead them to say on the basis of almost a thousand observations that this is a valuable aid in diagnosis. They warn, however, against depending upon it for the diagnosis of lead poisoning if there is any other form of intoxication to which the patient has been exposed, an exception which greatly lessens its value in difficult cases, and they also note that the urinary findings vary at different hours of the day. Naturally it is in those patients who show evidence of blood destruction that hematorporphyrinuria is to be expected. Thus, Legge and Goadby say that in jaundiced patients this substance is likely to be present in the urine. They believe that albumin will be found in well established chronic cases, but agree with von Jaksch that lead can be detected usually in the urine of acute cases only.

The significance of lead in the feces is of course not nearly so great as its presence in the urine, for the former shows simply excretion, the latter actual absorption into the circulation before excretion. Nevertheless in an obscure case, especially when there is doubt as to the history of exposure to lead, the examination of the feces may be of great help.

The appearance of basophilic granulations in the red cells, giving them an appearance of being stippled with blackish blue, was first described by Behrend according to Naegeli (19). Soon after, Grawitz (20), Litten (21) and Hamel (22) declared the presence of such cells in the blood to be the one sure diagnostic sign of plumbism. Moritz (23) succeeded in producing basophilic granules in the red blood cells of animals in experimental plumbism, and also showed that they may appear in man after no more than eight days work with lead. Grawitz said that not only were these cells always present in plumbism but that they increase with the increasing severity of the disease.

The subject was very thoroughly discussed at the meeting of the International Congress of Industrial Hygiene which was held in Milan in 1906, and it was generally held that the presence of these granules in the red blood cells could be regarded as proof incontrovertible of lead poisoning. But when the Congress met four years later in Brussels, dissenting voices were heard. Biondi insisted that this sign could be regarded only as confirmatory of a positive diagnosis; its absence did not mean a negative diagnosis. He held that the stippled cells are only youthful forms, not degenerated corpuscles. They simply indicate activity on the part of the blood-forming tissues and may be present one hour and absent the next. Oliver believed their appearance was very little help in diagnosis, in fact he could find them in only 40 per cent of his cases, and Rambousek on the ground of animal experiments (six out of seven rabbits) asserted that stippling of the red cells is neither an early nor a reliable sign of plumbism.

Naegeli (19) confirmed much of the work of Grawitz but was not willing to agree with him as to the frequency of this blood finding for he had found a complete absence of stippled cells in certain clear cases of plumbism. He also insisted that the number of stippled cells is in proportion, not to the severity of the poisoning, but to its duration. Other critics pointed to the finding of stippled cells in various forms of anemia. As early as 1902 Keil (24) described such red cells in the anemia of carcinoma, and in intoxication by salts of copper, cobalt, arsenic and thallium. He even claimed to have found stippled cells in the blood following carbon monoxid inhalation. Others have repeatedly found stippled cells in pernicious anemia, in Hodgkin's disease, in the anemias caused by blood parasites, in sepsis and in long-standing suppurative diseases, and Malden (25) says that they are quite as characteristic of chronic anilin poisoning as of chronic plumbism. (See page 493.)

Nevertheless as technique improved there were fewer negative or confusing results, and the appearance of red cells with basophilic granules in the blood of lead poisoning was common enough to make its value as an aid in diagnosis generally accepted. Much careful work has been done during the past fifteen years to determine the exact value of this sign and to help in eliminating errors.

The Hygienic Institute of Leipzig has had for some fifteen years a special clinic for workmen exposed to lead and in consequence it has been possible to test on a large scale various diagnostic procedures that have been advocated. Schmidt's (26) studies of the blood of lead workers and of controls have made him declare that while stippled red cells are not positive proof of plumbism, still they are seldom present in proportions over 100 to the million except in lead poisoning. Usually he finds 300 to 3,000 to the million. A lead worker with stippled red cells but in apparently perfect health he calls "a healthy lead carrier." Among 546 men from Leipzig lead trades 17.9 per cent had 100 stippled cells to the million and 9.2 per cent had more than that, while of 110 controls 12.7 per cent had as many as 100 per million and only 1.8 per cent had more than that.

Naegeli's 169 blood examinations gave the following results:

	Mild Cases, 134	Moderate Cases, 26	Severe Cases, 9
No stippling	25.5 per cent	11.5 per cent	11.0 per cent
Very few	30.0 per cent	11.5 per cent	11.0 per cent
Moderate numbers	33.5 per cent	23.0 per cent	0.0 per cent
Marked numbers	11.0 per cent	53.8 per cent	78.0 per cent

Carozzi (27), in his study of lead poisoning among the printers of Milan, says that he has found basophilic cells in the blood of these men, but not as often as in the blood of men exposed to the soluble compounds of lead, for their appearance depends on the rapid diffusion of the poison and in typesetting the diffusion is of the

slowest. He found polychromatophilia more often than basophilia, his figures being as follows: 135 printers examined, 23 or 17.04 per cent with basophilic cells; 35 or 25.92 per cent with polychromatic cells; 77 or 57 per cent with no abnormality in the red cells. Palmer and Ellis (3) examined 200 printers and found evidence of plumbism in 18, but only one had stippled red blood cells.

Cabot (28) points out a fact which should always be borne in mind in cases where the diagnosis depends on the appearance of basophilic granules in the red cells, namely that although these cells are found in other diseases it is only when the latter are accompanied by profound anemia, while in plumbism stippling is seen even when the anemia is of a mild type or perhaps not present at all.

Some of the recent articles on basophilic cells in lead poisoning deal especially with technic. Schilling (29) recommends the use of the "thick drop method" worked out by Ross for malarial blood and Schwarz and Hefke (30) have used it with great advantage. Schnitter (31) stains with a basic stain only, holding that a counterstain confuses the picture, for it allows only the coarser granules to appear. Using methylene blue alone he has succeeded in demonstrating basophilic granules in practically every case and in large numbers. Thus in the 98 cases examined in 1914-15 only one had less than 500 to the million, 12 had 500 to 1,000, 49 had 1,000 to 10,000, 34 had 10,000 to 50,000, and two had more than 50,000 per million. He therefore believes that there are no clinical cases of lead poisoning in which by proper staining these cells cannot be found, and he has seen them as early as two days after beginning exposure to white lead. In a series of 294 cases treated in hospital, only 5 per cent had fewer than 500 per million.*

An increased leucocyte count has been repeatedly found in lead poisoning. Cabot found leucocytosis in 10 of 15 cases, running from 10,000 to 23,400, the average for the 15 being 12,922. Boston (32) had 24 cases of acute plumbism, chiefly in white lead workers and all but three had white counts over 10,000. The highest was 25,500, the lowest 4,000, and the average for all, 12,600. Cadwallader (33), however, found a slight leucocytosis if any in the majority of his 37 cases. The count ran from 4,700 to 12,550, but averaged only 7,568. In 63 cases which have come under my observation in hospitals in Chicago, Philadelphia and Pittsburgh, the counts ran from 3,800 to 21,000, with 29 under and 30 over 10,000, and an average of 9,900. Only 6 were over 15,000.

* McJunkin, (34) working in Mallory's laboratory, came to the original conclusion that the basophilic granules in the red corpuscles are actually particles of lead, a lead compound which is soluble in protein-containing fluids, probably similar to lead alkyls. The lead absorbed from the stomach has, he assumes, been changed into this form within the bodies of endothelial leucocytes which have swallowed the particles in the stomach and intestines and conveyed them to the blood stream.

This leucocytosis has, as is well known, helped, in many instances of acute lead colic, to deliver into the hands of the surgeon a supposed case of acute appendicitis. Some years ago, when E. R. Hayhurst was an interne in the Cook County Hospital in Chicago, two girls who worked in a litho-transfer factory dusting lead colors on prepared paper were brought to the hospital suffering from what was diagnosed as acute appendicitis, and, naturally underwent appendectomy. It was only a subsequent attack of typical colic during convalescence in one of these girls and the appearance at the hospital of two more girls with the same symptoms that led Hayhurst, who was the interne in charge, to investigate the cause of this epidemic of appendicitis, and to discover a lead trade quite unknown at that time to Chicago physicians. Another case on my records is that of a commercial artist who used an air brush with white lead paint and also occasionally put his fine water-color brush in his mouth. He had an appendectomy, followed by an operation for the removal of supposed adhesions and was on the eve of a third operation, when a typical wrist drop at last revealed the real nature of his abdominal symptoms.

According to Legge and Goadby (9) such confusion can be avoided easily by making a differential count, for the increase affects the mononuclear cells, not the polynuclear, and a differential count of the white cells is of more diagnostic value than their actual number. Simon and Spillman (35), experimenting with guinea-pigs, found the leucocytic formula actually reversed in plumbism, the small mononuclears making up 70 per cent, the large 14 per cent and the polymuclear neutrophils only 12 per cent. This is, however, not always true. In Wolff's (36) case of extreme anemia there was a leucocytes of 25 000, actually one white cell to every 50 red cells, but the increase was confined to the polymorphonuclear leucocytes, which made up 86 per cent, the lymphocytes, large and small, only 2 per cent and the transitionals 2 per cent. Cadwallader failed to find a pronounced change in the leucocytic formula, but there was usually an increased proportion of large lymphocytes (averaging 14 per cent), at the expense of the small and sometimes of the polymorphonuclears. In the nine cases in which Poston made differential counts there were only two with deviations from the normal. One, an acute and fatal case of lead paralysis, had a polymorphonuclear leucocytosis, the other a case of colic, had a mononuclear leucocytosis.

The wide variety of white cell counts that occurs in lead poisoning may be illustrated by some records from my notes. Thus, I have two cases of chronic plumbism, one with a polynucleosis the other a mononucleosis. The first was a painter, with arteriosclerosis and Bright's disease, but no symptoms, at the moment, of acute lead poisoning. His white cell count was 7,250 with 93 per

cent polymorphonuclears. The second was a "lead worker" with palsy of hands and feet but no colic. His count was 4,800, with 76 per cent mononuclears, large and small, and only 21 per cent polymorphonuclear. The highest white cell count in my list, 21,000, was in a man who had been a painter for 20 years and was very anemic, red cell count 2,500,000, hemoglobin 40 per cent. The next highest, 19,600, was in a man who had been exposed to lead only a few months and was suffering from acute symptoms. He also was profoundly anemic, red count 2,240,000, and hemoglobin 60 per cent. There are five cases in which there was a polynucleosis, all of which had a very low red cell count, from 2,240,000 to 3,800,000, while in seven cases with a lymphocytosis there was only one with a red cell count lower than four million. In two of these last the number of white cells fell promptly as the acute symptoms of poisoning cleared up, dropping from 13,000 to 9,250 in one case and from 19,000 to 8,400 in the other.

In all cases of polymorphonuclear leucocytosis it would seem essential to rule out any possible focus of suppuration, but it is not often easy to discover whether this has been done. Indeed the whole subject of the changes in the leucocytes in plumbism is in a very unsatisfactory state and seems to have been neglected in the absorption of investigators over the question of the changes in the red cells.

Naegeli summarizes the blood findings in lead poisoning as follows: hemoglobin from 90 per cent to 100, a red cell count of four and a half to five millions, a few stippled red cells. Hayem (37) finds more marked changes than these. His description includes: slight increase in whites with a tendency toward mononucleosis, or a normal count; slightly lower erythrocyte count than normal; slight loss of hemoglobin; globular resistance somewhat increased; basophilic granules in the red cells. The finding of these granular cells in blood that is not markedly anemic renders the diagnosis certain, provided a history of exposure to lead can be elicited.

Cadwallader believes that the changes in the count and character of both red and white cells, when considered collectively, present a very definite and characteristic picture. For the red cells, this is a picture of slight anemia, with a most unusual proportion of stippled cells and normoblasts. In one case, while counting 500 leucocytes, he saw 130 normoblasts and 13 megaloblasts, yet the red count in this case was reduced only one quarter. In the blood from 37 cases of undoubted clinical plumbism the average red count was 3,850,000, the hemoglobin averaged 65 per cent, there were micro- and macrocytes, but poikilocytosis was not marked. The normoblasts disappeared in convalescence before the stippled cells, which last decreased slowly, and the red cells count went up very slowly,

in one case only 40,000 in four weeks, and with stippled cells still numerous even though all symptoms had cleared up.

Blum (1) says that for the diagnosis of lead poisoning it is usually sufficient to prove contact with lead, and the presence of the lead line merely strengthens the proof. The finding of basophilic granules in the red cells is helpful but they are not specific. The blood picture is never quite normal, but shows the effect of stimulation of the bone marrow. The blood pressure is important, not for diagnosis but for prognosis, for it indicates, if it is over 130-140 mm. the approach of the most dangerous complication of lead poisoning, the contracted kidney. It does not go hand in hand with chemical or microscopic changes in the urine. In lead workers a high pressure is more serious than in non-lead workers because the former are more likely to have lesions of the vascular system, as shown by the frequency of apoplexy among them. Among 39 men in a smelter 23 had a high blood pressure, five of them over 170 mm. It is important to make sure that the high pressure is constant, not momentary.

Perhaps the most valuable literature on the diagnosis of lead poisoning is to be found in the analysis of large quantities of clinical material on the basis of the frequency of certain signs and symptoms, such as have been made by several American and European clinicians.

W. Gilman Thompson (38) analyzed 64 cases to determine the relative frequency of the symptoms which are regarded as diagnostic of plumbism.

Colic, 45.

Line, 33.

Nausea and vomiting, 29.

Neuritis of arm, leg, etc., 23.

More or less palsy, 16.

Chronic nephritis, 19.

Slight febrile attack with colic, 13.

Moderate cardiac hypertrophy, 14.

Vertigo, 5.

Pains in major joints of limbs, 3.

As complications he notes five cases of gout and one each of the following: epilepsy, emphysema, hemoptysis, hematemesis, tuberculosis, convulsions, fatal apoplexy. The blood pressure was often high, 217 to 225, the last being in the case of apoplexy, a man of 45 years. The period of exposure to lead in these 64 cases was from 2 months to 45 years. Among 25 blood examinations, 17 showed stippling, 8 did not.

Apfelbach (39) takes as the "cardinal symptoms" of lead poisoning six: colic, constipation, pallor and anemia, blue line, stippled cells, tremor, but in his series of 72 cases only one had all of these six.

The most common combination was constipation, tremor and anemia, yet this he found only eight times. Constipation heads his list in order of frequency, occurring in 81.9 per cent. Colic is not nearly so frequent as in Naegeli's cases, being found only 31.9 per cent, but then Apffelbach distinguishes typical colic from abdominal pain, which if added would bring it up by 25 per cent. Fine tremor of the tongue was seen in 54.1 per cent, of the fingers in 18.1 per cent; neuritis in 18 per cent; loss of strength in the hand in 10 per cent; loss of general muscular strength in 10 per cent. He emphasizes the difficulties in diagnosis of lead colic, which may simulate renal or hepatic colic, intestinal obstruction, tabetic crises, angina sclerotica abdominalis, and most often appendicitis, with even tenderness over McBurney's point and a polynuclear leucocytosis. The confusion between these two has doubtless prevented operation on an appendicitis in a lead worker, and has perhaps more often led to operation on cases of lead poisoning.

Marvin Shie (6) of the U. S. Public Health Service examined more than 900 lead workers. He believes that too much stress has been laid on certain signs and symptoms of plumbism, which are really not so frequent as has been asserted. Pronounced anemia is rare, most of his hemoglobin estimations were between 80 and 100 per cent and the lowest were not below 65 per cent. Basophilic granulation of the red cells he found only once, and that in a recent case. He agrees with Hayhurst that the important finding in the blood in chronic cases is a "marked increase in the large mononuclear cells, ranging from 10 to 35 per cent." There is little aniso- or poikilocytosis. The Liebermann test for resistance of the red corpuscles is of diagnostic value in acute cases but worthless in chronic.

The symptoms that are to be looked for in lead workers according to Shie are pallor, muscular weakness, headaches, general asthenia, anorexia especially for breakfast, and constipation, but this last is not invariable and it is a mistake to decide against plumbism because there is no constipation. Rheumatism, muscular tenderness, abdominal pains, and nervousness are other symptoms which must be carefully weighed in a lead worker. "One of the greatest aids is a history of exposure. Without this knowledge lead poisoning will frequently be overlooked. With this knowledge plumbism should at least be considered in all obscure complaints arising among the workers."

Shie says that headache is the commonest symptom of involvement of the central nervous system, palsy the most serious. Marked tremor of the fingers, tongue, lips, and eyelids are nearly always present. He found the lead line in 90 per cent of his cases, an unusually large proportion, which may perhaps be explained by the mode of exposure of his patients who were chiefly potters working in an atmosphere rich in white lead dust, and refiners working in an

atmosphere of lead fumes. Menstrual disturbances were frequent among the women pottery workers. Hypertension, he believes, is not as common as has usually been believed except during an attack of colic. However, the particular lead industry has something to do with this, for while Shie did not find it among potters, he did find that the men in the refinery had a higher blood pressure than was normal for their age.

The statistics given by Wade Wright (40) of the Massachusetts General Hospital Occupational Disease Clinic show the great value of accurate methods of diagnosis in connection with occupational plumbism. During five years before the opening of this Clinic, only 147 cases of plumbism had been detected in the out-patient department, while in the first year after its opening 148 such cases were found. The diagnosis according to Wright should be based on the subjective symptoms, the lead line, examination of blood, urine and feces, and the history of exposure to lead. Stippling of the red cells is almost always found if a proper technique is used, and an almost equally characteristic finding is an increase of mononuclear leucocytes at the expense of the polynuclears.

The symptoms are first: pain in the lower abdomen usually associated with constipation (only 6 of 148 had diarrhea); second, weakness of the wrists, which comes next in order of frequency after colic, but true palsy is rare, seen in only 5 of the 148 cases; loss of appetite is common although not usually the earliest symptom, and nausea and vomiting are frequent; pain in the arms and legs is a common complaint, and still more often pain in the thighs, and there may also be pain in the lower lumbar and sacroiliac region, but this pain is not in the joints. A frequent symptom is pain and tenderness in the external condyle of the humerus which Wright believes is due to the fact that this is the point of attachment of most of the extensors of the forearm. The lead line was present in 78 of the 148 cases, not much over one-half. Wright advises rubbing lightly the edge of the gums with gauze, being careful not to start bleeding, in order to find the lead line. Sometimes a bluish black line may be found by everting the lip, on the surface next to the teeth. Pallor, weakness, loss of weight, insomnia, headache, vertigo, are all common complaints. Several of his cases had partial loss of memory, transient loss of consciousness, and minor mental disturbances. The urine was positive for lead 39 times, negative 87 times; the feces positive 58 times, negative 54 times. Twenty-two cases had lead in the feces but not in the urine, one only had lead in the urine and not in the feces.

Naegeli (19) says that too little emphasis has been laid on the variability of lead poisoning, on the fact that many cases are "mono-symptomatic" and the diagnosis must depend not on objective findings but on the word of the patient. Fifty out of 140 cases of mild

lead colic were monosymptomatic, that is, with only one objective sign, namely, the lead line in 20, tremor in 18, stippled red cells in 12. The other 90 cases were divided as follows: 19 had a line, tremor, and stippled cells; 18 a line and stippled cells; 40 a line and tremor; 7 tremor and stippled cells; and finally in 6 with typical colic, none of these three signs was present. In 200 cases studied by Naegeli, constipation was the most frequent complaint, present in 90 per cent, but absent in cases of "metasaturnism" that is, Bright's disease, cachexia, arteriosclerosis. Close to it in frequency comes colic with 89.5 per cent, following constipation in all but two cases in which it preceded, and absent in metasaturnism and in very mild forms of plumbism. In 25 per cent of the colics there was vomiting, all of these being cases of severe pain. Anorexia is very common but not invariable. The lead line was present in 57.8 per cent of the mild cases, 81 per cent of the moderate, 100 per cent of the severe. It may last for years without any symptoms, it cannot be relied on as an early sign for it depends so much on the condition of gums and teeth, and its absence can never be taken as a negative sign. Naegeli has seen the line disappear after 4 to 6 weeks of treatment, but in other cases it persists many months after all symptoms have cleared up. There is almost always a slight tremor, fine, characteristically more evident (in right-handed people) in the right hand and with the fingers spread. It seems quite independent of the other symptoms and is as pronounced in mild as in severe acute cases, but is especially well marked in metasaturnism.

Sternberg (41), who had great experience with Austrian lead workers, relies on the following signs: the lead line, lead in urine or stool, stippled cells and hematoporphyrinuria. Practically, the history of occupation, the lead line and the general appearance are enough.

Von Jaksch (14) says that, in spite of the variety of symptoms the diagnosis in a typical case is clear. Colic with a lead line makes it certain, doubt would arise only if there were no line or no history of contact with lead. The early symptoms are: vague disturbance of digestion, sense of pressure in the stomach, vomiting after eating, anorexia with metallic taste, and anemia.

Oliver in answering the question "What constitutes lead poisoning?" says that a blue line attended with symptoms, in a person whose occupation is known, is of considerable assistance in diagnosis. The lead line and lead in the urine show latent lead intoxication even if there are no symptoms at all. His description of a typical case follows: Pallor, and sallowness, metallic taste especially in the morning, distaste for breakfast. If the distaste for food is increasing, the individual should be suspended from work, for this is one of the earliest indications that the resistance to lead is diminishing. Obstinate constipation and a sense of tiredness out of propor-

tion to the amount of energy expended are also common complaints. The lead line is absent in the toothless.

Linenthal (4) says: "The symptoms of early plumbism are not well defined yet there is a group of symptoms which, when not open to explanation on any other basis, must, when a history of exposure to contact with lead has been obtained, be taken as evidence of early lead poisoning. Indeed it is important to inquire carefully as to any possible industrial exposure to lead whenever certain ill-defined states of ill health present themselves among workers, when such a diagnosis, for instance, as anemia, debility, constipation, lumbago or chronic arthritis, is made. * * * Pallor of the skin, muscular weakness, rheumatic pains, loss of appetite, constipation, or constipation alternating with diarrhea, abdominal pains, general nervousness, and persistent headaches, should always be regarded seriously when occurring in persons exposed to lead, or they may be the precursors to the more serious nerve lesions, such as wrist drop, encephalopathy, and to the more insidious and less dramatic changes in the vascular and excretory systems, arteriosclerosis and chronic nephritis."

Richard Müller, head of a great smelter-refinery at Ems, since deceased, told me that he instructed his foremen to watch the men at lunch and to keep under observation any man who showed an increasing distaste for his food. I have been told often by wives of lead workers that they could tell when a new attack of lead poisoning was imminent because they saw their husbands' lunch pails come home with the food untouched.

In the zinc smelters of Upper Silesia lead poisoning is much the most important industrial disease, caused by dust and fumes. According to Seiffert (13) the disease comes on slowly, is more often chronic than accompanied by acute colic. After one or two years' work in the smelter the man loses his fresh color, is sallow, his mucous membranes pale, in another year or so he is complaining of pressure and discomfort in the stomach, eructations after eating, loss of appetite. The lead line is visible by this time. At the end of ten years he has arthralgias and neuralgias, colics, vomiting, constipation and severe anemia. Later come palsies, chronic nephritis with edematous swellings, sometimes involvement of the cranial nerves and increasing mental deterioration.

Laureck (42) in Weyl's "Handbuch der Arbeiterkrankheiten," says that if a lead worker whose digestion has been good begins to suffer from chronic loss of appetite, more or less coated tongue, disagreeable, sweet taste, foul breath, eructation of gas, and general lassitude, one will seldom go wrong in making the diagnosis even if the lead line (absent in men who have lost their teeth) and the anemia have not yet appeared. Absolutely certain diagnostic symptoms for lead poisoning do not exist. Fleck (43), in the same en-

cyclopedia, says that "If a lead worker complains of weakness, trembling, loss of weight, foul breath, oppressive feeling in the stomach, itching of the eyelids, and spots floating before the eyes, a diagnosis of lead poisoning is probable. The presence of a lead line makes it certain." Meillère said (at the International Congress of Industrial Hygiene in Brussels—1910) that not only workmen but physicians often refuse to recognize anything as lead poisoning except colic or palsy, as sensible, he remarks, as to say alcoholism always means delirium tremens. He finds lead hysteria common and says, "Saturnism may be regarded as an intoxication capable of revealing or of exaggerating certain latent or abortive diatheses, usually hereditary, such as arthritis, gout, hysteria."

There is a special difficulty in diagnosing lead poisoning among printers, and the history of occupation, of exposure for many years to small quantities of lead, takes a very important place in the diagnosis. Typical lead poisoning is rare among printers; a history of acute lead colic is almost never obtained. Carozzi (27), from his study of the printers of Milan, gives the following description of typical plumbism in this industry: "Ill-defined symptoms of indigestion, loss of appetite, sense of fullness after meals, regurgitation of food or belching of gas, foul mouth, epigastric pains, increasing constipation, and sometimes enlarged and tender liver." He thinks arthritic pains are very common but not chronic nephritis.

Again and again in the discussion of the diagnosis of lead poisoning emphasis is laid on the importance of knowing whether or not the man has been exposed to lead. Indeed it is no exaggeration to say that the most important part of the history of a working man who is suffering from gastro-intestinal disease or from increasing loss of strength is the exact character of his occupation and it is a continual source of wonder to the industrial toxicologist that physicians and hospital internes should content themselves with information about the economic status of the patient and show no curiosity about his work. Even when lead poisoning is discovered there is seldom any attempt to trace the lead to its source and it is usually easier to discover from the history sheet the amount of tea, coffee and tobacco that the man has consumed than to discover where he got the lead which is obviously the cause of his illness. A safe rule is to suspect lead in any working man who complains of increasing weakness and loss of weight and vague ill-health, provided tuberculosis can be ruled out. If he is unable to give an understandable account of his occupation a simple test is to wet the skin of hands and forearms with a five per cent sodium sulphid solution, when the particles of lead will turn black and show plainly.

In countries where large numbers of workmen must undergo a periodical examination for lead poisoning it has been necessary to

work out a simple method which in practice will yield fairly good results, since it is of course impossible to use laboratory tests. Glibert of Belgium reported at the Congress of Milan in 1906 that the factory inspectors of that country had for some time used a dynamometer for testing the strength of the flexors and extensors of the hands of lead workers, for they found that a loss of strength in the extensors could be depended on as an early sign of plumbism. British industrial physicians also look for this sign in their routine inspection of workers in lead. In 1910 I saw Goadby make the usual weekly examination of the employees of a large white lead works in East London. The men filed slowly past him, each one pulling down an eyelid to show the color of the conjunctiva, and the lower lip to show whether there was a lead line. Then, as Goadby questioned him briefly as to appetite, constipation, general well-being, etc., he placed his own hands, palm down, on the back of the hands of the workman and tried to bend them, telling the man to resist. The difference in the strength of the two hands is often the first sign of plumbism, especially if it is the right that shows weakness.

Teleky (44) makes the test by having the man bend his elbow, pronate the hand so that the back is uppermost and then, with extended fingers, try to over-extend the wrist. He looks for a difference between the two hands and for an inability to extend the hand as much as 45 degrees from the horizontal. In twelve cases he found this an earlier symptom than the appearance of stippled cells. Ellis found in a group of 100 Chicago printers an average grip of only 97 on a dynamometer on which a control group of men in other occupations measured 120. A similar group in Boston were found by Palmer to average 112 while the control group averaged 129.

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CHAPTER 8

LEAD AS A RACE POISON

LEAD is often spoken of as a race poison, in that its effects are not confined to the men and women who are exposed to it in the course of their work, but are passed on to their offspring. The action of maternal plumbism upon the products of conception is clearly demonstrated, but the action of paternal plumbism is less striking. This is of course what one would expect. In the case of the man a poison can act only on the germ cell, but in the case of the woman the toxic action can continue throughout the nine months of pregnancy.

Statistics as to sterility of lead mothers, as to premature delivery, stillbirths, and mortality of babies during the first year of life, come chiefly from England. Arlidge (1), of Stoke, described the effect of lead on 71 women who worked in lead after marriage. Eleven per cent of the pregnancies resulted in miscarriage, and of the children born living, 37.7 per cent died. Legge (2) gathered from the reports of eleven factory inspectors for the year 1897, the following statistics concerning 77 married women lead workers. Fifteen never became pregnant; among the 62 who conceived, 15 never bore a living child; the stillbirths numbered 21; the miscarriages, 90; and of the 101 children born living 40 died; leaving but 61 living children from 212 pregnancies.

Oliver (3) quotes Reid's figures as follows:

Occupation		Mis- carriages and stillbirths	Deaths under one year per 1000 born
Housework	100 mothers	43.2	150
Mill work, not lead.....	"	47.6	214
Lead work before marriage....	"	86.0	157
Lead work after marriage.....	"	135.5	271

This table shows that mill work after marriage, even without exposure to lead, results in a high rate of infant mortality; while lead work before marriage increases the abortion rate; and lead work after marriage shows both these effects to an exaggerated degree. In addition, Prendergast (4), who had a large experience in the pottery towns, says that the living children of leaded mothers are less strong than the children of mothers free from lead.

English investigators have also shown experimentally that lead brings about the death of the embryo. Oliver painted two series of fertile eggs, one with lime and the other with nitrate of lead. All the former produced live chicks, not one of the latter did, the embryos reaching only a limited stage of development and then dying. Legge and Goadby (5) observed that the animals used in their lead experiments, if pregnant, always aborted. Constantin Paul (6) has the credit for first making known this effect of lead, a statement confirmed six years later by Arlidge of Stoke. Porak (quoted by Deneufbourg (7)) produced experimental lead poisoning in pregnant animals and succeeded in finding lead in all the organs of the offspring of leaded mothers, distributed far more evenly than it is in mature individuals. Balland (8), a pupil of Pinard, also succeeded in isolating lead from the prematurely born, weak, and small offspring of leaded guinea-pigs. He found lead in the milk of a lead poisoned woman and in the milk of a bitch experimentally leaded. Meillère (9) and Pinard (10) both found lead in the premature children of leaded mothers. The form of plumbism in women which is most likely to produce disastrous effects on pregnancy is the slow, chronic type. Ganiayre (11) relates the histories of four lead-poisoned women who, after 19 pregnancies, had only two children surviving the first year of life. In the body of a four and a half month fetus and in the brain and liver of a prematurely born child who died after 48 hours, he found lead. There were traces only in the fetus, but more in the child, and still more in the placenta. Tardieu (12) reported to the French government in 1905 that 608 out of 1,000 pregnancies in lead workers resulted in abortion.

The fact that in the United States so few women, relatively, are employed in dangerous lead processes, has made us speculate more on the question of whether plumbism in the father may possibly affect the offspring, a question of much greater practical importance for us. Legge and Goadby (5) find very little evidence that a man lead worker is less likely to beget children or that his children are more likely to be unhealthy than are those of men working in any other industrial process. Nevertheless there is evidence, based on statistics and confirmed by animal experiments, to show that lead poisoning in the father affects the offspring disastrously. The statistics as to paternal plumbism in human beings come from France, and the figures most often quoted were published by Constantin Paul (6) in 1860. Lewin (13) seems to have borrowed them in 1904 and to have republished them without quotation marks, and as German literature is read more in America than French, Lewin is usually credited with them. Paul's statement is as follows: Seven wives of lead workers who had given evidence of plumbism had 32 pregnancies, of which 11 ended in abortion, and

one in stillbirth. Of the 20 children born living, eight died in the first year, four in the second, five in the third, and one after the third, leaving only two alive out of 32 pregnancies. Similar figures are quoted by Gilman Thompson (14) as given by Rudeaux in 1905. He says that out of 442 pregnancies in women married to lead workers 66 ended in abortion and 241 in premature birth.

Deneufbourg, a pupil of Pinard, wrote a thesis in 1905 on the effects of parental plumbism upon the products of conception, using as a basis the abundant material of the Baudelocque Obstetrical Clinic of Paris. He divided the cases into three groups: first, the women married to lead workers but themselves free from lead; second, the women who were leaded but married to men free from lead; and third, the women leaded themselves and married to leaded men. The number of pregnancies, premature deliveries, and stillbirths, and also the proportion of living children who died during the first year of life are given in the following table.

	No. pregnancies	Abort.	stillb.	Per cent	Born living	Survived 1st year	Per cent of living offspring surviving 1st year
Fathers leaded	442	66	47	25.5	329	246	74.4
Mothers leaded	134	17	6	17.	111	82	73.9
Both parents leaded..	23	4	4	35.	15	10	66.6

It is of course in the third group that the effect of the lead is most striking. If we compare the two other groups, the effect of paternal plumbism seems to be quite as disastrous as the effect of maternal, and indeed the abortion rate is actually higher; but the second and third groups are too small to be taken with much seriousness.

These statistics of Deneufbourg's are much the most convincing that have been presented to show the influence of paternal plumbism on the human offspring.

Professor Oui (15) of the University of Lille gives the history of a healthy woman, 38 years old, free from any suspicion of syphilis, and married to a man of 41 years, not syphilitic or alcoholic, who soon after marriage took up the occupation of printing, and in a few years began to suffer attacks of lead colic. The record of the woman's pregnancies runs as follows: First, in 1890, healthy child at term, still living; 2nd, died of meningitis at 8 months; 3d, died at 4th month; 4th, died on 13th day; 5th, premature delivery of macerated fetus; 6th, delivery almost at term of macerated child; 7th, delivery at 6½ months of macerated fetus; 8th, macerated fetus; 9th, delivery at 6½ months of macerated fetus; 10th, delivery at term of macerated child; 11th, present pregnancy, now 7th month and woman has not felt fetal movements for three

weeks. She was delivered of a macerated fetus. The most interesting feature in this history is the increasing effect of the lead, the reverse of what is seen in syphilitic infection, and it is still more striking when to the history of the present marriage is added the first marriage made by this man; for that resulted in the birth of a healthy child, still living at this date. Thus, before he took up lead work this man had begotten two healthy children, but from that time on the effect of his occupation on the germ cell became increasingly disastrous.

Oui mentions a case of Pinard's which was quoted by Brouardel, that of a woman married to a lead-poisoned man, who was pregnant five times and always prematurely delivered of a dead child, and who then bore to a healthy man a perfectly normal child. Pinard called it an experimental demonstration of the effect of paternal lead poisoning.

Seeligmüller's (16) statement before a medical meeting in Halle, in 1901, as to the influence of paternal plumbism on the offspring is often quoted, but he offers no proof of his assertion that the effect of lead is comparable with that of syphilis, since lead may injure the products of conception, although the mother remains quite unaffected.

This rather slender evidence is strengthened by some experimental studies made by Cole and Bachhuber (17) at the Wisconsin Agricultural Station, and by C. V. Weller at the University of Michigan. Weller used commercial white lead—basic carbonate—and fed it in capsules to guinea-pigs. The experiments which interest us especially are those with leaded males, and these are some typical results which he obtained:

	Free Female Mated with:	
	Free Male	Lead Male
Number of offspring.....	58	65
Average birth-weight, grams.....	81.5	66.3
Number stillborn	3	3
Died first week.....	2	9

The effect of alternate matings of the same normal female with a normal and with a lead male is also interesting. For instance, the birth weights of the offspring of a free male were 79 gm. in two instances, and of a lead male 54, 47, and 40 gm.

The results of paternal lead poisoning in guinea-pigs are shown not in sterility or in stillbirth, but in reduction of weight at birth, and this underweight persists through life. Next to this the most striking change is the high rate of mortality during the first few days after birth. Nine out of 65 offspring of leaded males died during the first week, but only two out of 105 offspring of control males.

Hall (19), of Aguascalientes, describes widespread family poisoning among the women and children living in a smelter village close enough to the stacks to breathe the fumes, which apparently are not caught in flues, but escape. He says that lactation is affected among these Indian women, 22 per cent of whom were unable to nurse their children, although the multiparae had been able to nurse the children born to them before they came to the smelter village. Parturition was rendered difficult through uterine inertia, a condition ordinarily rare among Indian women. He found lead several times in the placenta. Among the children born in the village, 80 per cent had delayed dentition, the first tooth coming as late as the 30th month. Children coming to the village with old mastoid infections suffered relapse, and old rheumatoid affections became active again.

Roque (20), in a Paris thesis of 1873, first described abnormalities in the children of leaded parents, gathering his material from the clinic of the Salpêtrière. Nervous disorders, such as idiocy, imbecility, epilepsy, were very frequently found in such children, especially if both parents were leaded. Nothing is said here to show whether or not the lead trade carried on was a tenement house industry, in which case the children themselves might have been poisoned. This possibility must be borne in mind when one reads of the children in pottery villages in Germany and Hungary, as described first by Rennert (21), and later by Chyzer (22) and by Oliver (3). Rennert, in 1881, found in the village of Almerode, where pottery glazing was at that time a home industry, an enormous prevalence of convulsions among the children, and also of a peculiar form of macrocephaly, with square-shaped head which developed slowly and was not accompanied by imbecility. He called it "hypertrophy of the brain" on the ground of his findings at autopsy and of the shape of the skull. He gives the following records of 79 children:

	No. of Children	Macro- cephalic	Convul- sions	Still- births
Both parents leaded.....	19	18	17	1
Father leaded, mother slightly.....	27	17	9	6
Father leaded, mother healthy.....	33	19	13	0
Total	79	54	39	7

There were 56 out of 79 children with either macrocephaly or convulsions or both, making 71 per cent affected. The mortality was 50 per cent: in the first group, 72 per cent; in the second, 17 per cent; and in the third, 60 per cent. Rennert says that the fetus is apparently more susceptible to lead than the mother, being affected by quantities too small to injure her. The hypertrophy of the brain he attributes to injury to the paternal germ cell.

Chyzer (22), some 27 years later, published a description of the pottery villages of Hungary, where conditions were much the same as those found by Rennert, and where the same peculiar form of macrocephaly prevailed among the children. His findings were confirmed in 1909 by Oliver, who made a special journey to Hungary to study this form of hereditary plumbism. Of course it must be remembered that the opportunity for actual lead poisoning is always present in these cottages where lead glaze is in constant use, and indeed Rennert found some children with typical plumbism, palsy of the peroneal muscles, and of the extensors of the toes.

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CHAPTER 9

TOXICITY OF LEAD COMPOUNDS. COMPOUNDS USED IN INDUSTRY

TOXICITY OF LEAD COMPOUNDS

ACCORDING to Leymann (1), Rambousek (2), Blum (3), Etz (4), and Beck (5), the toxicity of a lead compound is in direct proportion to its solubility in weak hydrochloric acid and they, therefore, classify the compounds used in industry on this basis.

Beck found the nitrate, acetate, and chlorid soluble even in water. Easily soluble in weak acid (0.1 normal hydrochloric acid), are the oxids, carbonate, basic carbonate and monosilicate; slightly soluble in weak acid are the sulphid, sulphate, chromate and disilicate, their solubility being in that order.

Etz's series is as follows: in the least dangerous class are sulphid ore and metallic lead; in the next, precipitated sulphid, iodid, sulphate, red lead (Pb_3O_4); next, the carbonate, chromate, and peroxid (PbO_2); next the basic carbonate, and the suboxid (PbO); and in the most poisonous class, the acetate, nitrate, and chlorid.

Blum, Rambousek, and Leymann find the acetate and the basic carbonate (white lead), to be the most poisonous. The iodid, sulphate and oxids work more slowly. The presence of peptone in artificial gastric juice (one per cent peptone in 0.25 per cent HCl), increases the solubility of white lead, according to both Rambousek and Blum, while Carlson (6) says that peptone in concentration of 0.2 per cent and 1 per cent does not have a marked influence on the solubility of the lead salts, but so far as the influence of the peptone is in evidence it may be explained as follows: The formation of lead peptone compounds might lead to the setting free of the chlorin ions in the lead chlorid, and thus to the formation of more lead chlorid from the carbonate and the sulphate. His figures show that this is not an important factor in lead poisoning from the digestive tract.

Oliver (7) considers red lead less poisonous than white lead, giving rise to less severe symptoms, but he quotes Layet as saying before a Congress of Hygiene, in Turin in 1880, that the oxids were the more dangerous and more likely to give rise to encephal-

opathy. My own experience would lead me to believe that the oxids are more dangerous than white lead. It is usual in the United States, as in Great Britain, to produce in the same plant both white lead and the oxids, litharge and red lead. On the continent the roasting of oxids is a branch of lead smelting. In two factories in this country in which the medical records of white lead men and oxid men were kept separately the rate of poisoning in 1911 was higher in the oxid department and the average period of employment was shorter. For instance, in one factory the rate was 22.5 per cent for the white lead department and 58.3 per cent for the oxid. The average period of employment for the white lead men was four years, but for the oxid men, one year.

Lead sulphate began to invade industry as a substitute for white lead in paint manufacture and in rubber compounding about 25 years ago and it has gained a very important footing in American industry. Lead sulphate is also produced in large quantities in smelting the sulphur-containing ores. It was long believed, and the belief was fostered by skilful advertising by the lead sulphate producers, that this compound was insoluble in the body fluids and therefore not poisonous to human beings. Ten years ago it was still not uncommon to find physicians advising lead workers to drink freely of what was called sulphuric acid lemonade, under the impression that the lead which had been ingested would be thereby changed to the sulphate and excreted harmlessly. Goadby (8), in testing white lead, the sulphate, and litharge with human gastric juice, came to conclusions quite at variance with those universally held. He digested these compounds for an hour at 37° C., then centrifuged and titrated the fluid with ammonium molybdate, one c.c. of which equalled 0.0008 gm. of lead oxid. He found the sulphate actually more soluble than the other two, as much as 80 per cent passing into solution, while of the white lead only 48 per cent, and of the litharge only 40 per cent, did so. These results are contradicted by those of A. J. Carlson and C. Woelfel (9), who in an elaborate series of tests with human gastric juice, found the basic carbonate far more soluble than the sulphate.

Carlson and Woelfel's tests were made not only with these two compounds, but with the dried paint dust rubbed from painted steel plates with sandpaper, just as would be done in the course of painting Pullman cars. They found that the solubility of the lead salts in pure gastric juice is practically the same as that in similar quantities of 0.5 per cent HCl, which last is then shown to be the all-important solvent. Basic lead carbonate is a little more than twice as soluble as lead sulphate, but the latter is soluble to a considerable extent, thus:

118 INDUSTRIAL POISONS IN THE UNITED STATES

RELATIVE SOLUBILITY OF LEAD CARBONATE (OLD DUTCH PROCESS) AND BASIC LEAD SULPHATE (SUBLIMED WHITE LEAD) IN HUMAN GASTRIC JUICE

Lead sulphate			Lead carbonate		
Experi- ment number	Digestive mixture	Lead dissolved	Experi- ment number	Digestive mixture	Lead dissolved
		Grams			Grams
1.....	{ 25 c.c. gastric juice; 25 c.c. water; 0.5 g. lead sulphate, at 38° C. (100.4° F.) for 10 hours.	{ (a) .1260 (b) .1210	1.....	{ 25 c.c. gastric juice; 25 c.c. water; 0.5 g. lead carbonate, at 38° C. (100.4° F.) for 10 hours.	{ (a) 0.2940 (b) .3044
2.....	{ 25 c.c. gastric juice; 25 c.c. water; 0.5 g. lead sulphate; 0.1 g. peptone (a), 0.5 g. peptone (b), at 38° C. (100.4° F.) for 10 hours.	{ (a) .1376 (b) .1284	2.....	{ 25 c.c. gastric juice; 25 c.c. water; 0.5 g. lead carbonate; 0.1 g. peptone (a), 0.5 g. peptone (b), at 38° C. (100.4° F.) for 10 hours.	{ (a) .3302 (b) .3100
3.....	{ 50 c.c. gastric juice; 0.5 g. lead sulphate, at 38° C. (100.4° F.) for 10 hours.	.1500	3.....	{ 50 c.c. gastric juice; 0.5 g. lead carbonate, at 38° C. (100.4° F.) for 10 hours.	.3896
		Per Grams cent			Per Grams cent
Average	{ (1) 0.1235 = 24.7 (2) .1330 = 26.6 (3) .1500 = 30.0		Average	{ (1) 0.2992 = 59.8 (2) .3201 = 64.0 (3) .3896 = 77.9	

The samples of paint dust gave similar results, the average solubility of the sulphate being 9.5 per cent, of the carbonate 46.1 per cent.

There are two factories in the United States which make sublimed lead, or basic sulphate of lead, and in both the process is extremely dusty and the men breathe large quantities of finely divided sulphate. In both places the method of obtaining the sulphate is essentially the same. It is a sublimation process, the fumes from blast furnaces (known as "slag-eyes"), passing through gooseneck flues to end in large dust bags where the fine blue or white sulphate powder collects. The coarser powder, used in manufacturing rubber, falls into hoppers from the flues, but the finer, which is the basis of paint, has to be shaken out of the bags. Twice in their 8-hour shift the men enter the great bag house where cotton bags hang in rows like enormous organ pipes, and walking in among them they beat or shake them to dislodge the sulphate which has collected inside. It is easy to understand what an excessively dusty piece of work this is. The sublimed sulphate is very light and fluffy and so full of air that it is difficult to pack down and requires pounding and tamping.

In one of these plants, where 45 or 50 men are employed in the lead-sulphate department, a system of regular medical examinations had been instituted a little while before my investigation was made in 1912, and the physicians' records showed that 18 of the sulphate men had been examined recently. Two of them had to be left out of consideration, as they had been employed for less than four weeks, but of the remaining 16, 11 showed the lead line on

their gums and five showed evidence of plumbism, a proportion of almost one in three. In the second plant no records were kept and no information could be obtained from the company doctor, but a search among the employees brought to light 12 recent cases of acute plumbism among the 45 men employed in the sulphate department. Of course this did not include all of the lead-poisoned men, and there was no reason to think that the proportion of men poisoned is lower here than in the first factory.

It can be seen, therefore, that the basic sulphate is distinctly poisonous and none of the precautions advocated for the protection of white lead workers should be neglected for those handling lead sulphate.

A striking reduction in the incidence of plumbism among painters was effected by a railway car company which had, up to 1912, always used white lead paint for interior work in coaches and also for the outside of passenger coaches. They then adopted sublimed lead paint (basic sulphate), and at the same time introduced modern sanitary precautions and medical supervision which up to that time had been entirely lacking.

The physicians' records covered three periods, the first running from July 1 to December 31, 1911, during which time the company was experimenting with lead-sulphate paint and carrying on investigations to ascertain how much lead poisoning there was among the painters. During the second period, from January 1 to March 1, 1912, lead-sulphate paint was used exclusively, but sanitary provisions for the painters were not yet complete. The third period, from March 1, 1912, to April 20, 1913, represents the present state of affairs, viz.: Basic lead-sulphate paint, excellent sanitary equipment and supervision, and regular medical inspection. During the first six months an average of 489 men were examined monthly, and 109 cases of plumbism were discovered, giving an average of 18 a month. In the next two months, making the second period, an average of 649 men were examined and 16 cases of plumbism found, or 8 a month. The third period covers more than 13 months, and during this time the average number of men examined monthly was 639 and only 3 cases of lead poisoning were found. Thus the lead poisoning in this workshop fell from an average of 18 cases a month in a force of 489 men to an average of $\frac{3}{13}$ case a month in a force of 639 men.

The physicians who were interviewed maintained that this great improvement was to be attributed to the institution of medical and sanitary care, not to the change in the paint, while the foremen were inclined to give the credit to the paint. The truth is that both were factors. Without the sanitary supervision, some men would probably have been poisoned even with the sulphate paint, but there could never have been so great and so sudden a falling off of

lead poisoning if the company had continued to use the carbonate paint, no matter what care was taken. There is no record in the literature of such a rapid improvement following the institution of sanitary measures alone.

The controversy over the poisonousness of lead sulphid has been as keen as its importance warrants; for this is the form of lead to which lead miners are universally exposed and most of them do not come in contact with any other form. The older mines contain practically all galena, only the more recently mined deposits, such as those in Australia and in the western States still produce the so-called oxidized ores, the carbonate, sulphate, oxids. Therefore, if any plumbism is found in the mines of England, Italy, Austria-Hungary, or Missouri, it can be assumed to be due to lead sulphid. Oliver says that lead miners in England practically never have poisoning. Rambousek asserted at the first International Congress of Industrial Hygiene at Milan in 1904 that lead sulphid ore was non-poisonous,* that in the mines of Pribram there had not been one case of plumbism among some 5000 miners. Biondi (10) opposed this, saying that he was willing to admit that the sulphid was the least poisonous but that it was not harmless; for he had seen the usual signs of lead absorption among the lead miners of Sardinia and had found lead in the urine. It is very exceptional now to see serious cases of colic or palsy or encephalopathy, but formerly, when conditions were bad, these were common.

Murgia (11), who was experimenting on dogs and rabbits with blende—zinc sulphid—found lead as well as zinc in the liver and intestines. The blende was contaminated with small quantities, not more than 0.2 per cent, of lead sulphid and this had evidently been absorbed and reached the liver. It was, however, Brezine and Eugling (12) who definitely settled the question of the absorbability of lead sulphid. In their effort to reproduce in animals the lesions of slow, chronic poisoning they selected various lead compounds, the carbonate, sulphate, oxids, metallic dust and the sulphid and introduced them into subcutaneous pockets, then examined the blood for the appearance of stippled red cells. They used guinea-pigs whose blood had been carefully examined before the experiment. The basophilic granules appeared on the second day after introducing the oxids, on the sixth after the carbonate, and on the twelfth after both sulphid and sulphate, but they were much more numerous in the sulphid animals than in the sulphate. They even succeeded in bringing about this blood change after 26 days by rubbing on the shaved skin lanolin with 10 per cent of lead sulphid.

The solubility of lead sulphid was determined by A. J. Carlson who tested the lead sulphid and galena ores with human gastric juice.

* Blum was unable to kill rabbits with it, although they succumbed to the acetate, basic carbonate, chlorid, oxid, iodid by mouth.

Carlson digested 0.5 gm. of the ore with 25 c.c. of human gastric juice, and 25 c.c. of distilled water at 38° C. for ten hours. He found that of the galena ore from the smelter at Federal, Ill., 2.94 per cent passed into solution; of the ore from Desloge, Mo., 1.38 per cent; and of the ore from the St. Joseph Lead Company (Herculaneum, Mo.), 3.32 per cent dissolved. A specimen of laboratory lead sulphid was somewhat more soluble, 4.6 per cent passing into solution.

In smelting these lead ores the sulphid is quickly burned to the sulphate and the poisonous quality of the fumes and dust in smelting is largely due to finely divided lead sulphate.

The solubility of the chromate was worked out by E. Leymann (1) who found that it produced in cats lead poisoning as quickly and intensely as did lead sulphate. Single doses of both salts were well borne, the action was cumulative.

How much the solubility in human gastric juice has to do with the actual toxicity of the lead compound cannot as yet be stated. Practically it seems to be a fair test of the danger of a given mixture. The British law brings under special rules all establishments in which mixtures containing as much as 5 per cent soluble lead are used, and solubility is determined by the so-called Thorpe test, namely by digesting the mixture with 0.25 per cent of hydrochloric acid for two hours and estimating the lead as PbO.

Practical experiments with lead compounds in industry shows that the danger of a given compound depends quite as much on the physical properties as on the chemical; for if a given compound is light and fluffy it will do more harm than one that is far more toxic but not dusty.* For instance, lead acetate gives no trouble, although it is soluble even in water. But it is sticky, so that it does not contaminate the air, and it has a sour taste so that a man is conscious of it at once if any gets into his mouth. Litharge, which is not nearly so soluble, is tasteless and is also very light and fluffy, extremely troublesome to handle and productive of much plumbism.

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COMPOUNDS USED IN INDUSTRY

The compounds of lead with which the industrial workers come in contact are:

Metallic lead, the bright surface of which soon becomes coated with a dark film which is believed to consist of suboxid of lead Pb_2O .*

Oxids: PbO which is formed when lead is heated in the air. This collects on the surface of lead kettles as dross. It is also formed, together with $PbSO_4$, when lead sulphid ore is smelted.

PbO , massicot, is formed when lead is only moderately heated, litharge when the heat is greater. This oxid is used in the making of storage batteries, compounding rubber, making varnish, and as an oxidizer in the preparation of linseed oil.

Pb_3O_2 , red lead, is made by heating massicot. Commercial red lead has usually a composition corresponding to $3PbOPbO_2$. It is used in paint, in making storage batteries, and glazes, and enamels, and glass.

PbO_2 is known as the brown peroxid. It forms the material for the "action mass" for storage battery cells, and is found covering the old lead plates in repair shops. It is used as an oxidizing agent in the manufacture of anilin dyes.

Basic carbonate, or white lead or Old Dutch Process white lead: This is lead carbonate with a variable quantity of hydroxid, approximately $Pb(OH)_2 \cdot 2PbCO_3$. It is used in paint, putty, pottery glaze, by plumbers in "joint wiping," sometimes in rubber compounding.

Sulphate: $PbSO_4$ occurs in the so-called oxidized ores of the less deep mines. It is one of the chief constituents of the fumes and flue dust found in smelting lead.

Basic sulphate or sublimed white lead: This is lead sulphate, $PbSO_4$, with a varying proportion of the hydroxid $Pb(OH)_2$. It is used in paint and sometimes in rubber compounding.

Chromate: $PbCrO_4$ is used as "chrome yellow" in paint and dyes

* C. L. Bloxam, *Chemistry, Organic and Inorganic*, Philadelphia, 1923, p. 483.

and mixed with Prussian blue it forms "chrome green." Chrome orange is a basic lead chromate, PbCr_4PbO .

Sulphid: This is the form in which lead chiefly occurs in nature. Miners and metallurgists handle it.

Acetate: $\text{Pb}(\text{C}_2\text{H}_3\text{O}_2)_2$ is used in the production of lead compounds, especially the chromate.

CHAPTER 10

LEAD MINING. LEAD SMELTING AND REFINING.

ZINC SMELTING. METALLIC LEAD

LEAD MINING

LEAD mining is carried on chiefly in southeastern Missouri, in Utah, Idaho, and Montana. The Missouri ore is practically pure galena, lead sulphid, but the western ores are nearer the surface, and oxidized ores are still mined in various regions. For instance in Utah the Park City district and the Tintic and the Frisco districts, especially the last, still produce large quantities of carbonate ore. The rate of lead poisoning in a mining community depends upon the dryness of the mine and on the proportion of carbonate and oxid ores, which are more soluble than sulphid ore and therefore more poisonous. The deeper the mine the greater the proportion of sulphid. St. Vincent's Hospital in Leadville, Colorado, has records running back to 1880 and in those early years from forty to fifty miners a year were treated in the hospital for lead poisoning, but by 1910 the number had fallen to eight, and in 1912 there were none at all.

The great lead mines at Broken Hill, Australia, were notorious for lead poisoning some years ago, but now the carbonate ore is largely exhausted and there is far less trouble. There is, however, chronic lead poisoning among the men who handle only pure sulphid ore. (Birks (1).) It is also true that cases of lead poisoning develop in the galena mines of southeastern Missouri, although their number is probably not great.

An investigation made by Arthur L. Murray (2) for the Bureau of Mines, relative to lead poisoning in the mines of Utah, was published in August, 1921. It is evident from Dr. Murray's figures that lead poisoning is by no means rare in the mining communities of this state. He sent a questionnaire to the physicians of Utah, asking for cases of lead poisoning occurring in 1919 and 1920. Two hundred and fifty-six doctors and dentists answered, sending returns which covered 70 per cent of the population of Utah. A total of 371 cases was reported for 1919, 224 for 1920, making 595 for the two years. Some of these, however, came from the three great smelters at Midvale, Murray, and Tooele, but 282 of the 371, or 76 per cent, were in miners, and 186, or 83 per cent, of the 224.

These figures give case rates for the whole population of 0.83 per thousand in 1919 and 0.5 per thousand in 1920, an enormous figure considering that Utah is predominantly an agricultural and stock raising state.

Bingham is the largest center, and the mines there have been worked for many years, the levels are now below the oxidized ores and not dry, and the rate of poisoning is almost nil. Next lowest is the Ophir region, where there is a deep sulphid mine, with a rate of 5.9 per cent in 1919, 1.3 per cent in 1920. Park City and Tintic are dry and still mine a little carbonate ore. They had rates running from 13 to 15 per cent. The highest incidence of poisoning was in Frisco where the mines are exceptionally dry and dusty and there is a larger proportion of carbonate ore than anywhere else. In 1919, 16.8 per cent of the men had plumbism, and in 1920, 27 per cent. The rate for the whole mining industry of Utah was 6.7 per cent in 1919, and 5 per cent in 1920.

A recent report of the New South Wales (Australia) Commission on White Lead, published in Sydney, Australia, in 1922, gives the result of an intensive clinical study of the mine employees, miners and surface and underground workers of Broken Hill during 1919, made by Professor Chapman and Dr. S. A. Smith, with special regard to the effect of lead. The lead is in the form of sulphid and oxid with small quantities of carbonate. Sixteen hundred and ninety-seven miners were examined and 277, or 16 per cent, showed indications of lead poisoning. The proportion of positive cases among those exposed less than ten years was 8.3 per cent; of those exposed more than twenty years, 33 per cent. Among 2271 underground workers, not including miners and surface workers, 197, or 8.6 per cent, were positive for lead. These investigators had the opportunity to make post mortem examinations of the bodies of eight lead miners. They found lead in the lungs of seven, and the eighth man had not been working as a miner for twelve years past.

Certainly these studies of sulphid mines in Australia and in Utah show that the work is not nearly so harmless as it was declared to be by Rambousek and others.

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LEAD SMELTING

An investigation of lead poisoning in the smelting and refining of lead was carried on by the U. S. Bureau of Labor Statistics in

1912 and 1913. It covered 20 plants situated in Perth Amboy and Newark, N. J.; East Chicago and Gracelli, Ind.; South Chicago, Federal, Collinsville and Granite City, Ill.; Herculanum and Joplin, Mo.; Omaha, Nebr.; Pueblo, Leadville, Denver, and Salida, Colo.; Murray, Midvale, and Tooele, Utah; and East Helena, Mont. There are also five plants in California, Washington, Idaho, and Texas which were not covered by this inquiry.

These plants had an average daily pay roll of 7500 men, the great majority of whom were Austrian Slavs with fairly large numbers of Magyars, Italians, and men from the Balkan states. Only in the Missouri smelters are there many American-born, and here and in southwestern Illinois Negroes also are employed. It is unskilled or semi-skilled work for the most part, the wages are not above the average, and the labor turnover is very great. An eight-hour day is usual, but the yard gang works ten hours, excepting in Colorado, and twelve hours was the rule in the plants near Chicago.

The ore is chiefly galena, lead sulphid, exclusively so in Missouri; but the western ores still contain carbonate and oxid. In the eastern smelters these ores arrive at the smelter already crushed and screened, in the form of concentrates, but in the western smelters crushing and screening are done at the plant. Work at the mill where the ore is crushed, sifted, and mixed with other ingredients is almost always very dusty although it would be perfectly possible to prevent the dust. As it is, mill hands are frequently poisoned, and in one crushing mill 14.3 per cent of the employees in this department came under the doctor's care in two months' time with lead poisoning. A Negro employed in one of the Illinois smelters for six months, handling lead ore, had an attack of colic, constipation, headache, and a lead line was visible on his gums. In connection with the crushing department we often find a sampling mill where samples of ore are reduced to different sizes. This place must be kept clean, because if dust were allowed to blow about no sample would be pure. However, although no accumulations are allowed on floor or table, the small mills and sieves and the iron plates (known as bucking boards), must be cleaned after each sample and this is done by shaking and by brushing off the dust with a dry brush. This dust has been ground as fine as possible and sometimes the air of the room is quite cloudy with it. The sampling room is generally recognized as a fairly dangerous place to work in, and in one mill with a payroll of 30 men there were 27 cases of lead poisoning in one year.

The crushed ore goes through many processes of roasting and smelting. Pure galena ore is worked up without pre-roasting in some smelters, but usually various forms of preliminary treatment are considered necessary. Of these the most important are the

Huntington-Heberlein pots and the Dwight-Lloyd roast-sinter machine. The former give much trouble with dust and fumes, especially when discharging. German factory inspectors found a distinct increase in the number of cases of lead poisoning in a smelter in the Wiesbaden district after the introduction of these pots, *i.e.*, from 7 per cent to 11 per cent. Huntington-Heberlein pots were found in 1913 in seven plants (the converter-roasters in Midvale are essentially the same), and the number ran from 8 to 60 pots. Usually they are placed out in the open air, and during the roasting there is little danger from the slight escape of fumes. It is in dumping and breaking up the roasted ore and in conveying it to the crusher that the danger of fumes and dust is very great. The great kettle is lifted and carried by a traveling crane to the dump and there tipped over, the hot, fuming mass falling with a crash on the grating over the dump. Sometimes a spray of water is then turned on it, to wash down the "fines," the powder that has escaped the caking process, but the water does not really soak in far and the inside cake is still dry. The men then move forward and chop at the cakes and push them through the grating to the crusher, working in a cloud of dust and fumes. It is said that these fumes contain only 10 per cent of lead, but that is quite enough to give a great deal of trouble.

The Dwight-Lloyd method is a down-draft roasting and sintering process. The well-mixed and moistened charge is fed to a moving grate from a hopper; the grate moves slowly forward bearing its four or five inch layer of ore over the edge of a suction box and under a flame playing down from above. The flame is drawn by the suction down toward the charge, ignites it, and the gases formed pass down into the suction box. The chemical and physical changes are accomplished during this passage under the flame so that at the end of the machine the cake which breaks off and falls into the discharge is both roasted and sintered. The empty grate passes down along an endless belt and up again to the starting place; the gases and fumes go from the suction box to the flues and bag house. This method can be used in such a way as to obviate all risks, provided there is a positive suction at all points where gas or fume is formed, and provided the ore is damp at the feeding point and a hose plays over the cake when it falls at the discharge. If these features are neglected the Dwight-Lloyd machine may be a source of great danger. Grate cleaning is a bad feature; for the charge sticks somewhat to the grate and the bits must be clipped off with an air hammer. A mechanical cleaner attached to the grate is the only proper device for such work.

Roasting and smelting may be combined in one operation in the case of a simple compound such as lead sulphid, and we find in the smelters using Missouri ore the furnaces commonly known in Amer-

ica as Scotch hearths or ore hearths, and in Germany and Austria, as American hearths. This is the simplest process still in use for smelting lead. It is an open hearth, usually provided with an inner hood and a wide spreading outer hood to catch the fumes, a lead well to one side, and a slag car on the other side. Two men work the hearth; they stir the charge with pokers and toss the hot slag first out on the work-plate or apron, then into the slag car, and they guide the melted lead into the lead pot. The work is practically uninterrupted during the shift. Whenever the fire blazes up well through the smoothed-off mass the latter must be stirred and thrown back and more coke and ore added. The work is hard and hot and as it is paid for on a piece-work basis the man must work assiduously to make full wages; for the least neglect injures the production. There are no pauses for lunch and if the man stops he does it at his own loss. About 50 per cent of the charge is recovered from the ore hearth as metallic lead, almost 35 per cent goes into the gray slag, and the remaining 15 per cent, into the fumes. One plant had 30 such hearths; another, 24; a third, 16, and at every visit I made to an ore hearth building I found the air cloudy with lead fumes. The wages paid are comparatively high, but the force shifts very strikingly in spite of that. I paid a second visit to one plant after an interval of three years and the foreman pointed out to me as an "old hand" a man who had been there when my first visit was paid. He and two others were the only ones left working there after three years.

The pre-roasted ore, the gray slag from the ore hearth, and the flue dust go to the blast furnace for smelting. Usually this runs continuously, except when it is closed down for repairs. A "slag-eye" is a small blast furnace built to volatilize lead and is used for the production of sublimed white lead for paint. There are two points of special danger in the blast furnaces,—the charge floor from which the mass of prepared ore is emptied into the furnace, and the tapping floor where at different levels the melted slag, matte, and lead are drawn off. The fumes and dust on the charge floor can be entirely prevented and this is done in several American plants, but the difficulties are greater on the tapping floors. The lead runs out at a low red heat, fuming always more or less; but usually the lead pot is to one side and the fumes do not reach the men as much as do the fumes from slag and matte. Slag is tapped every ten minutes or so and the fumes are very abundant, but slag alone usually contains not more than 1 per cent of lead. Matte contains from 13 to 20 per cent, and matte tapping is the worst feature of the work on the tapping floor. It must be done about every 40 minutes, and always dense clouds of fume are given off for several minutes. Devices for carrying off fumes from these sources are very imperfect in most plants and quite lacking in some.

The safest tapping floor I have ever seen was in the great refinery at Ems in the Rhineland which was at the time of my visit under the charge of Richard Müller (1), the chief authority on the prevention of lead poisoning in this industry. Müller had inclosed his tapping floor completely; for in this way only could he have an efficient artificial exhaust system. In American smelters the tapping floor is always practically out of doors and we rely on dilution of the fumes rather than on efficient fume removal; for, of course, a system of drafts which is at the mercy of wind and weather cannot be depended on. The tapping floor in the Ems smelter was in a very clean building with white-washed walls. Over the lead tap and the tap for slag and matte a large hood was fitted, the pipe with a strong suction going to the flue system. A window in this hood allowed the workman to open and close the tap with a long-handled rod and he was not allowed to wheel away the lead pot, or slag- or matte-car, until the contents had cooled.

Müller places blast furnace tapping in the most dangerous class if fumes are allowed to escape, but if proper devices are installed it may be classed with the comparatively safe jobs. All fumes on the tapping floor, whether lead, slag, or matte, must be regarded as a menace. The managers of American smelters usually acknowledge the danger from matte fumes, but look on the fumes from the lead tap as negligible, because they are never very heavy, and in fact are visible only close to the pot. The fumes from the slag pot they consider practically safe, because there is supposed to be less than one per cent of lead in the slag. Both these opinions Müller regards as very erroneous. The fumes from the lead pot are practically pure lead oxid, and as for the slag pot, the fumes contain a much higher proportion of lead than does the slag itself. He has found by analysis of slag fumes that there may be 12.3 per cent of lead, and Hofman (2) found a far greater quantity of lead in the fumes from a boiling slag pot, no less than 41 per cent lead monoxid and 26.2 per cent lead sulphate. Müller's analysis of matte fumes gave 18.8 per cent lead.

The softening and refining furnaces are usually mechanically charged and are emptied through tapping or by a siphon. The same sort of furnace is used in refineries for melting old lead and lead scrap of all kinds. This work can be rendered fairly safe if the charge is damp, the charging mechanical, and if there is a well constructed hood with a good draft to carry off the fumes when the furnace door is open for raking and when the hot slag is skimmed off and the lead discharged. As a matter of fact, refineries, which should be far safer than smelters because the process requires so much less heat, may actually be more dangerous by reason of poor equipment and careless handling of dusty charges.

Some refineries use an electrolytic process to obtain pure lead.

The work in the cell room is free from dust, but precautions are needed at the kettle where scrap lead is melted for the starting sheets, in casting the starting sheets, in melting up old sheets and drossing the melting kettles, in working up the dross in reverberatory furnaces, and especially in handling the "anode mud," the product of electrolysis. This wet mud or sludge is said to consist of lead, silver and gold in metallic form, with arsenic, antimony and copper in compounds as yet undetermined. It must be treated in reverberatory furnaces and in preparation for this it is dried in dust chambers. Transporting and charging this dry powder is very dangerous.

The by-product or residue furnaces, the copper converters, and the retorting and cupelling furnaces are often very prolific sources of fumes, and the arsenic present in many by-products may be a great source of trouble. Müller believes that if precautions are not taken to prevent the escape of fumes, work on the retorts and cupels may be as bad as that at the blast furnace, and an additional danger at the cupels is the dust caused by breaking up by hand the cakes of litharge.

The dust and fume collection system in a modern American smelting or refining plant is very large and elaborate. Usually steel flues pass from the roasters and blast furnaces to great brick flues high enough for a man to enter and these in turn pass on to the bag house which is filled with cotton bags in which the very lightest flue dust is finally deposited. Steel flues are usually emptied every three or four weeks through windows which permit the flue cleaner to insert a bent pole and to scrape out the dust or, if the flue is very large, permit him to enter and to shovel it out. A better arrangement is the placing of hoppers at intervals along the flue, where the dust falls and from which it can be removed through a canvas chute. The brick flues have doors which are bricked up except during cleaning time, every three to six months.

The flue dust is a bluish black powder, light and fluffy, consisting chiefly of lead oxides and sulphate and, in western smelters, of large quantities of arsenic oxide. Brick flues are always entered by the workman and the dust shoveled out. The dust from the bags is shaken down either by reversing the current of air and thus causing a vacuum which makes the bag collapse, or by a shaking mechanism. The dust falls then into brick tunnels on the ground floor. Sometimes the contents of a tunnel are burned in order to make the dust sinter or cake, or it may be shoveled out without burning. I have seen many tunnels emptied and always the work was very dusty. The burning made the dust cake in masses like coral rock but the men never waited for it to cool off and the fumes more than

made up for the lessening of the dust. Usually the work is done on contract, not by the regular force. In the western smelters the flue dust contains a high percentage of arsenic, and this makes it necessary to protect the men by providing overalls, helmets and gloves, and a bath house with hot water, soap and towels. In other smelters the precautions taken are not so great and in one the manager told me that his yearly flue-cleaning had resulted in no less than 40 cases of acute lead poisoning. The only way to do away with the dangers in this department would be to flush out the flues and the tunnels of the bag house. Metallurgists assure me that any plant could do this if it had the proper slope, but the men in charge insist that it is possible only in making sublimed lead when all the SO_2 is combined, and also in connection with copper converters; for the fume from other furnaces contains too much SO_2 and sulphuric acid would form. However this may be, the one plant which in 1913 did use flushing has since given it up.

The rate of lead poisoning found at that time was very high, 1769 cases having occurred in 19 plants during the year 1912, and this did not nearly represent the full number; for only two plants had a full medical record, and in four plants no information at all could be obtained. The cases reported by physicians and hospitals represented a rate of twenty-two per hundred employed. The British rate for that same year for lead smelting (zinc not included), was 1.8 per cent. Neither the German nor the Austrian rates were nearly so low as the British, but they were much lower than the American. Three German plants had rates of 10.6 per cent, 11 per cent, and 16.6 per cent, and one Austrian plant had a rate of 9 per cent.

The records of six American plants show the following proportions of plumbism among about three thousand men in one year's time:

No. 1.....	18.0 per cent.
No. 2.....	18.2 per cent.
No. 3.....	27.5 per cent.
No. 4.....	28.3 per cent.
No. 5.....	34.0 per cent.
No. 6.....	52.3 per cent.

An examination of these records shows that the Scotch hearths, including the small hearths known as "slag-eyes," and the flue and bag house system gave rise to more poisoning, and to a greater proportion of severe forms of poisoning than any other work. For instance, this table shows the record of the three ore hearth plants, compared with all the others:

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	19 Plants	3 Ore Hearths	Per cent of total in 3 Ore Hearths
Employed	7400	1000	13.5
Cases of plumbism.....	1769	397	22.4
Encephalopathy	41	29	70.7
Palsy	35	19	54.3
Death	16	9	56.32

When there are no ore hearths the blast furnaces and the flues and bag houses are responsible for the most trouble. At one such smelter, records were available of 174 men who had recently been examined by the physician. The incidence of plumbism in the different departments was found to be as follows:

Occupation	Number examined	Cases of Plumbism	
		Number	Rate per 100 employees
Yard gang, unloading, wheeling charges, etc.	26	5	19.2
Furnaces	119	37	31.1
Bag house and flues.....	8	5	62.5
Miscellaneous, refining, repairing, masons, etc.	21	3	14.3

Another record, which throws light on the danger of different kinds of work, was kept during two months of 1913 in a plant employing regularly 622 men. In these two months 65 cases of plumbism occurred. The men were employed as follows:

Ore bins	Rate 13.3	per 100	employed
Mills	14.3	" "	"
Sintering	10.0	" "	"
Blast furnace feeding.....	20.0	" "	"
Blast furnace tapping.....	23.3	" "	"
Settling furnace for matte.....	33.3	" "	"
Converters	6.7	" "	"
Bag house and flues.....	42.9	" "	"
Miscellaneous	2.5	" "	"

On the tapping floor of one smelter 23 out of 54 men showed signs of chronic plumbism and in another, out of 65 cases of lead poisoning, 21 came from the tapping floor, making one-third of all the cases in the plant, although the tappers formed less than one-sixth of the force.

Histories of 167 cases among smelter men show a short period of exposure in the great majority. Eighteen had been exposed less

than one month before sickening; 121, less than six months; 11 between six months and one year; 35, over one year; of whom only five had been exposed more than five years. I obtained records of 41 cases of encephalopathy, 35 of palsy, and 16 of death from lead poisoning.

The erroneous idea that lead poisoning is caused by lack of personal cleanliness, that the man is poisoned by the lead which clings to the skin and is carried into the mouth with food or tobacco, has taken deep root in the smelting industry. I once heard the head physician of one of the largest American companies make the statement at a medical congress that the lead smelter man was poisoned not by the lead to which he was exposed during his working day but by the lead which he carried home with him at the end of his work. The physician in charge of one of the great Utah smelters told me that the greatest danger to the men in the smelter came from the lead which got under their finger nails and which they were too careless to remove thoroughly. I had just been out to this smelter and had seen the discharge of one of the great Huntington-Heberlein pots. The traveling crane carried the pot to the dump and inverted it till the tons of smoking, fuming ore, red hot, fell with a crash on the grating. As the smoke cleared a little I could see the men breaking up the cakes and pushing them through the grating. The air was thick with fine dust and fumes and yet these were the men who were being urged to protect themselves by scrubbing their finger nails. The only way to explain the holding of such opinions by medical men is to assume that they have never seen the actual working conditions of the men whom they are treating.

Collis (3), of the Factory Inspection Department in Great Britain, says that in the smelting of materials containing lead, handling of lead may be practically disregarded as a source of trouble. Laureck (4), describing the smelting industry of Germany, says that unquestionably the greatest danger to the workmen is the contamination of air by lead dust and lead fumes. Yet, strangely enough, in the United States both physicians and laymen connected with lead smelting plants almost invariably lay greater stress on the danger of uncleanness on the part of the workmen than on anything in his surroundings. Charge men on feed floors with leaking stacks, workmen tapping matte and lead from the blast furnace, men working in clouds of dust and fume at the pots or the roast and sinter machines, all are supposed to get leaded from eating their lunch without washing their hands. One argument against this view seems to have escaped them. The product handled in a smelter or a refinery gets richer in lead as it goes through successive processes, and therefore the dust that adheres to the skin has more and more lead in it as the end of the process is neared. Refiners and desilverers are handling practically pure

lead, and so there should be more lead poisoning in that department than in the mill, or in charging, or in breaking up the roasted ore, or in blast furnace work where the dust has only a relatively small proportion of lead. But every practical smelting man knows that refining and desilvering are about the safest kinds of work in the whole plant.

Richard Müller, who has written the most thorough treatise on lead poisoning in this industry, goes thoroughly into the question of the comparative danger of carrying lead into the mouth by dirty fingers and of breathing lead-contaminated air. He found the lead content of one cubic meter of air in the flue over the slag tap, at the level of the workman's mouth, to be 1.184 gm. Estimating that this would be diluted about five times at the tapping platform he calculates that there would be 0.2368 gm. in each cubic meter breathed by the tapper. As a man breathes about 4.5 cubic meters in ten hours, the tapper would breathe 1.0625 gm. in the course of his ten-hour day. On the other hand, Müller found only 0.0876 gm. in the wash water from the hands of a man who had been working ten hours on the tapping floor, and from the hands of a second man only 0.032 gm. Obviously, it would not be possible for the men to get even all of this lead in their mouths by eating with unwashed hands; unless they literally washed their hands in the soup or coffee.

The analyses of dust and fumes in lead smelting, shown in table on opposite page, were made by Hofman and quoted by Collis in the English report already referred to.

Zinc ore commonly contains some lead, and zinc smelting is attended with lead poisoning. Among the zinc smelters of Upper Silesia * lead poisoning, caused by dust and fumes containing lead, is much the most important industrial disease. According to Seifert (5) the disease comes on slowly, and is more often chronic than characterized by acute colic. After one or two years' work in the smelter the man loses his fresh color, is sallow, his mucous membranes pale, in another year or so he is complaining of pressure and discomfort in the stomach, eructations after eating, loss of appetite. The lead line is visible by this time. At the end of ten years he has arthralgia and neuralgias, colics, vomiting, constipation and severe anemia. Later come palsies, chronic nephritis with edematous swellings, sometimes involvement of the cranial nerves, and increasing mental deterioration.

According to Legge (6) 19 of the 56 cases of lead poisoning in the smelting trades in Great Britain in 1912 were contracted in zinc smelting.

A large zinc smelting company in Colorado made in October, 1912, an examination of 345 employees to determine how many showed

* See chapter on Zinc.

ANALYSIS OF DUST AND FUMES

Percentage of Poisonous Chemicals in Dust and Fumes from Various Sources

Material Analyzed	Arsenic	Arsenious Oxid	Lead	Lead Mon-oxid	Lead Sulphate
	Per cent	Per cent	Per cent	Per cent	Per cent
All dust collected in 10 years, Average .....	....	....	25.6	....	....
Dust from—					
Down comers of 11 blast furnaces.	....	....	47.5	....	....
Roof of blast-furnace buildings....	....	....	27.1	....	....
Hood above slag tap .....	....	0.6	....	28.5	27.1
Fumes from—					
Slag pot while boiling .....	....	4.8	....	41.0	26.2
Reverberatory settling furnace ...	2.3	....	....	31.0	....
Flue dust from—					
Friedrichshütte, Silesia .....	....	....	....	62.8	....
Příbram, Bohemia .....	....	1.0	....	45.5	....
Freiberg, Saxony { A....	7.5	....	25.2	....	....
B....	37.5	....	21.3	....	....
C....	46.4	....	16.2	....	....
Flue dust from—					
Omaha and Grant Works, Denver.	....	15.8	....	....	57.3
A....	.3	....	18.7	....	....
Globe Works, Denver { B....	.3	....	12.6	....	....
C....	....	....	5.1	....	....
D....	....	....	19.4	....	....

evidence of lead poisoning. The furnace force numbered 163 men. The physicians found 11 men with positive signs of plumbism, all but two of them being furnace men. Eighty-two men showed a lead line, all but six of them being furnace men. Twenty-one men had a history of acute plumbism, the attack in many cases having been fairly recent, and 14 of these were furnace men. Less certain signs of plumbism were noted in 14 men employed as machinists or yard men, only one of them being on the furnaces. It is noteworthy that a furnace man, who had been employed only one month, already showed a distinct lead line, and another furnace man had an attack of lead colic after three months' work.

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METALLIC LEAD

Metallic lead is used in a wide variety of industries where it is cast or molded into various shapes. Lead wire, sheet lead, pipe, machine parts, plumbers' goods, bullets and shrapnel, picture frames, coffin ornaments, grids for storage battery plates, car and can seals, stoppers for bottles and for basins, tin foil, lead foil, printers' type, all these are objects the making of which involves exposure to molten and solid metallic lead, and in connection with all of these, cases of industrial lead poisoning are on record. There are also industries which we associate with more dangerous forms of lead and which have metallic lead departments also. Thus, in white lead manufacture the process starts with the casting of lead buckles. Other industries involving a large use of metallic lead are the making and use of solder and of bearing metal,* lead burning with the oxyhydrogen flame, and lead tempering of machine parts, piano wires, magnetos, etc. The plumber's trade is less a lead industry than formerly but repair work with "joint wiping" means exposure to lead. Among 560 cases of industrial plumbism collected by the Illinois Occupational Disease Commission, in 1911, 19 were in plumbers.

The dangers in all these trades are comparatively slight and easily controlled. To prevent poisoning the workers with fumes and dust it is only necessary to carry off the fumes from the lead pots, which is usually a simple affair, and to insist on strict cleanliness. Of course the amount of dust produced is very slight unless there is gross carelessness. European regulations for lead molding and casting, trimming and finishing, etc., require that the room in which such work is done be whitewashed at least once a year and that the floor be of impervious material, smooth, never swept dry, but cleaned with water or oil, while the surfaces of work benches, windowsills, cabinets, ventilation pipes, etc., must be cleaned with wet cloths.

The very lack of evident and immediate danger in the use of metallic lead seems to be at the bottom of the neglect of ordinary precautions in so many American plants where soldering, remelting used metal, casting, trimming, etc., is carried on.† For instance,

* Babbitt metal is supposedly lead-free, consisting of copper, tin, and antimony, while bearing metal has lead displacing the tin, but in practice all varieties are called Babbitt if they contain copper.

† Among the cases of encephalopathy described in Chapter 6 are two which occurred in men working with metallic lead, one with bearing metal, the other with solder. I am indebted for the history of the latter to Dr. L. G. Rountree

the Illinois State Factory Inspection report for 1917 tells of a can factory which had a long soldering machine running down the center of a room in which there were 100 employed. There was no hood over the molten lead, no artificial ventilation, and in December, when the windows were all closed, 18 cases of lead poisoning developed. In the same report we find the record of a can and car seal factory employing 188 persons, chiefly girls, at molding and trimming. Twenty-eight cases of lead poisoning occurred here in one year.

The higher the temperature of the molten lead, the greater the exposure to fumes, and it is probable that lead burners have the most dangerous job among the workers with metallic lead. Lead burning consists in melting together two surfaces of lead to make a solid joining. An oxyhydrogen or hydrogen-air flame is used, and the heat is great enough to cause volatilization of the lead, while the danger to the worker is much increased by the necessity he is under to put his head inside the receptacle or to climb into the acid tank which is being lined. Engelsmann (1), in 1922, found that in two industrial establishments in Germany, each employing 41 lead burners, 22 men in one and 25 in the other, suffered from lead poisoning. Ten had had two attacks, and one had had three. Engelsmann says that neither the appearance of stippled cells nor a rise in blood pressure can be depended upon to give warning of a threatened attack. The diagnosis must be made on the clinical picture: a feeling of fatigue, especially in the knees, loss of appetite, sluggish intestinal movements, and then sudden colicky pains radiating from navel and stomach, and complete constipation. In 31 out of 41 lead burners whom he examined he found mixed poisoning. These men always suffered from typical zinc chills immediately after they had welded zinc parts together.

Lead tempering is attended with exposure not only to lead fumes but to lead dust. Machine parts, piano wires, magnetos, are tempered in a bath of molten lead, taken out, hung up to cool, and then brushed to get rid of the gray oxid coating which has formed. Kenney (2) gives the history of a case of severe lead poisoning, colic, anemia, general weakness, wrist drop, in a man who had been tempering magnetos for eighteen months. The use of solder with a small Bunsen burner, as for instance in burning the connections of storage batteries, presents some difficulties; for, although the heat of the tiny flame is not great, yet it is impossible to remove whatever fumes are formed by means of local suction; for the draft would deflect the flame and make work impossible. In cases such

of the Mayo Clinic, who tells me that this man worked for three years soldering tin cans, had an attack of typical acute plumbism with abdominal symptoms, "then developed wrist drop and foot drop with definite evidences of lead encephalopathy."

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as this, the effort must be to dilute the fumes by very abundant general ventilation.

Brass foundry work, especially pouring, is not an uncommon cause of lead poisoning; for brass contains as a usual thing an appreciable quantity of lead, sometimes as high as nine per cent. For the same reason we sometimes find lead poisoning in brass polishers. (See page 284.) I remember a case of double wrist drop in an Italian brass polisher who was referred to me as an instance of unusually severe brass poisoning. When questioned, he said that four months previously the exhaust on his polishing wheel had got out of order and that he had been afraid to complain and so had worked on, inhaling the dust that the exhaust had formerly carried off.

That work with metallic lead is far less dangerous than work with a soluble salt is evident to anyone who studies such an industry as the making of white lead; for the "blue buckle" department where the lead buckles are cast is, in a clean factory, practically a safe place to work, while all the later processes involving the handling of white lead must be elaborately safeguarded. I gathered some statistics from storage battery work which showed the difference between work with metallic lead and with the oxids. The following table gives them:

	Employees	Cases of lead poisoning	Per 100 employed
Metallic dust and fumes.....	303	3	1.0
Oxids	274	39	14.2
Both	338	28	8.3

Nevertheless, very serious forms of plumbism do develop in men whose work does not bring them in contact with lead in any form except the metallic. For instance, among the records in the Cook County Hospital is that of a man who handled pig lead for ten months, came to the hospital with an acute attack of plumbism and a history of chronic symptoms, and whose blood showed profound anemia, 3.4 million red cells, hemoglobin 58 per cent. Another, also with an acute exacerbation of chronic plumbism and with a marked anemia, had only been handling lead, copper, and brass in a foundry. Dr. Andrew M. Harvey, of the Crane Company, Chicago, told me of a case of plumbism in a man who handled solid brass only and was not exposed even to brass fumes. One of the cases of encephalopathy described in Chapter 6 was contracted by work with bearing metal and babbitts. There is a striking case reported by John M. Andrews (3), in his study of sixty cases of fatal plumbism in New York State. A lad of 18, apparently vigorous, weighing 165 pounds, went to work in a factory making tin pails and cans with lead solder. The place was poorly ventilated.

At the end of six months he had lost weight, was pale, and exhibited symptoms of lead poisoning. He went back to work but was obliged to quit before the end of the year, and he lived only five months more. Typical lead colic came on only a short time before death. There are six other cases of poisoning from metallic lead among Andrews' sixty, one of whom, a printer, died at only 28 years of age. The others were all older and had usually been exposed for many years; four were printers, one a lead molder, and the other a maker of pipe and shot.

A very extraordinary case, one which has no parallel in the literature, was reported in 1920 by Lubbers and Keulemans (4), of Amsterdam, who found in the feces and urine of a type founder metallic lead which appeared as a sediment in the urine and was washed out of the feces. They estimated that the man got rid of about 0.25 gm. of lead in the three weeks after he left work. He had colic, a lead line, and stippling of the red blood cells. The extraordinary statement that metallic lead was found in the urine seems to be based on specimens of urine brought in by the man. The hospital analyses seemed to be of feces only, and it would certainly seem possible that the man had deliberately swallowed lead dust and also mixed it with his urine.

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CHAPTER 11

THE PRINTING TRADE

THE unhealthful features of the printing trades are the following: It is an indoor occupation, often carried on in ill-ventilated rooms; it requires little physical exertion and in consequence the printer's circulation is likely to be sluggish and he is likely to be over-sensitive to cold; the nervous strain is great, perhaps greater than it used to be when the hours were longer; and, finally, the printer is exposed to the effect of various poisonous substances, the most important of which is lead.

The sources of lead dust are: in the composing room, the dust from type cases; in the linotype room, the scraps of lead from the machine which fall on the floor and are ground to powder by the feet of passers-by, and the dust from cleaning machine and plunger; in stereotyping and electrotyping, the scraps from trimmers and routers and saws, and the dross from the kettles. In addition, most shops melt and re-cast old type and scrap, and this is another source of lead dust.

Lead poisoning may also be acquired by exposure to the fumes from molten lead in stereotyping, electrotyping and in re-melting and casting type.

The material in this chapter was gathered by me for the U. S. Bureau of Labor Statistics in 1916, during a study of the printers' trade in America, the object of which was to discover what influence, if any, the presence of lead and of other less important toxic substances has upon the men engaged in the printing trade, and incidentally to observe all the features of the industry which might have an indirect bearing upon health. In order to do this, I visited 130 plants in seven of the largest cities,—Boston, New York, Philadelphia, Baltimore, Washington, Chicago, and St. Louis. As there are in this country no complete statistics of sickness among printers available, it seemed best to make a physical examination of groups of employed printers, taking so far as possible a typical cross section of the industry. Dr. Walter W. Palmer (1) examined a group of 100 Boston printers and Dr. John D. Ellis (1) a similar group in Chicago. In addition to these examinations a careful study was made by Mr. Charles H. Verrill of the Bureau of Labor Statistics of the sickness and death records kept for many years by the International Typographical Union.

Type metal is an alloy of lead containing antimony, tin, and copper. A great variety of mixtures is used, according as hard or soft type is desired. Linotype metal is usually soft, which means that it is rich in lead and poor in antimony, while stereotype metal has more antimony, and monotype metal has still more. The proportions used are kept secret, but I have been informed that tin is too expensive to be used in large quantities and its place is often taken by lead. Dr. Earle B. Phelps (2), of the Public Health Service, analyzed the various type metals used in the Government Printing Office and found their composition to be as follows:

Metal	Melting Point	Lead	Antimony	Tin	Arsenic	Copper
		Per cent	Per cent	Per cent	Per cent	Per cent
Linotype ..	237° C. (459° F.)	84.3	9.5	4.4	....	....
Monotype .	236° C. (457° F.)	75.3	16.3	6.9	....	....
Electrotype.	265° C. (509° F.)	91.9	3.0	4.1	....	....
Stereotype .	236° C. (457° F.)	77.2	14.7	5.7	....	....

There is a wide difference of opinion among foreign authorities on the printing trades as to whether or not lead fumes are given off from the melting pots of the linotype or the monotype machines, or from molten lead in stereotyping and electrotyping. That lead has an appreciable and measurable vapor pressure at all temperatures above its melting point is known to all metallurgists and contamination of the air above a lead kettle is always possible, although it would be very slight if the lead were not much above the melting point. Hahn (3) looked into the question, on complaint of the linotypists of Germany, but came to the conclusion that the symptoms the men complained of were caused by eye strain and possibly by lead dust and gas fumes from the heating apparatus, but not by the fumes of lead. An Austrian authority, Etz (4), says it is quite impossible that linotypists could be poisoned through fumes from the lead pot and the only danger comes from careless handling of lead dross which easily becomes dusty.

A number of analyses of air over melting pots have been made in Germany and Austria to determine this point, but it seems evident from the descriptions of these experiments that they were all done with the molten lead at rest. Now if one watches the work at a lead pot no fumes can be seen while the lead is undisturbed, but as soon as it is stirred or fresh lead is dropped in or the dross skimmed off, or if it is ladled or pumped out into molds and pans, a very distinct bluish cloud may be seen rising. Therefore, the Bureau of Labor Statistics asked Dr. Earle B. Phelps of the Public Health Service to test the air under conditions reproducing the actual conditions in the plants; that is, with molten lead more or less agitated.

Dr. Phelps used type metals of the same composition as those in the Government Printing Office and raised them to the same temperatures. He also carried the temperature higher in order to cover those shops in which variations of heat are not well regulated, and the lead is sometimes allowed to reach a higher point than is necessary. He collected air for analysis while the molten metal was at rest and then again while it was being agitated. Dr. Phelps summarizes his results as follows: "There is no detectable volatilization of lead within the range of temperature used at the Government Printing Office or at a considerably higher temperature, but even at the lowest temperature used there is a formation of oxid upon the surface of the molten metal, this oxid film being in the form of finely divided dust. It is more or less affected by mechanical agitation and may quite readily be carried away by currents of air. In practice it is frequently skimmed off as dross. Under the conditions of these tests and, it is believed, under conditions as observed in the Printing Office, this last effect is the only one deserving serious attention. It is primarily a matter of mechanical agitation rather than of the temperature of the metal, which determines the pollution of the surrounding air with this fine metallic dust."

In other words, molten lead as used in printing is at a temperature below the point when lead fumes in the strict sense of the word are given off, but stirring or skimming or ladling or otherwise disturbing the film of oxid constantly forming on the surface of the lead, detaches it and allows it to be carried into the air so that there is, as shown by actual test, a contamination of the air with lead. This is probably the reason why it is considered safer to have all melting pots provided with hoods, and most of the foreign authorities who do not believe that lead fumes are a danger in printing, nevertheless, to be on the safe side, advise this precaution.

Whatever doubt there may be as to the presence of lead in the fumes from melting pots there is no doubt that the air of the printing shop may become contaminated with lead dust in several ways. The dust in type cases contains lead, and some of it escapes when the type is shaken to get at the lower letters, and especially when the cases are cleaned by blowing out the dust. Around the linotypes and the machines for trimming, shaving, and routing stereotype and electrotypes plates, there are heaps of lead scraps and filings, which are tracked about by the men passing to and fro. The melting pots are surrounded by lead scraps and by even dustier dross that is skimmed off and very often thrown on the floor. Then at the end of the day's work the linotype machines are cleaned, sometimes by wiping, but much more often by brushing or blowing out the scraps of lead. The linotype plunger must be cleaned every now and then, in some cases every day. This may be done in an enclosed machine,

but if it is done by hand with a wire brush, a very distinct cloud of gray dust comes off. In all of these ways particles of lead find their way into the air of the composing rooms and of the stereotype and electrotype foundries.

Analyses of dusts collected in various printing shops have been made in Germany, Austria, Italy and England. None of them show a large proportion of lead in the dust from any source except the type cases, and this does not often find its way into the air of the rooms; for even in printing shops where type is used over and over again the type cases almost never have to be blown out as often as once a week.

Dr. Phelps analyzed eleven specimens of dust from the Government Printing Office and from three newspaper printing offices in Washington. The results were as follows:

	Per cent
Sample 1: Newspaper Office	0.51 lead
" 2: Newspaper Office	0.8 "
" 3: Newspaper Office	2.8 "
" 4: Job printing	0.2 "
" 5: Job printing	5.68 "
" 6: G.P.O. Open Type Case.....	5.68 "
" 7: G.P.O. Dust 2 ft. from floor.....	0.64 "
" 8: Monotype case	5.12 "
" 9: Back 4 ft. high.....	0.72 "
" 10: Old type case.....	0.32 "
" 11: Tops of cabinets.....	0.64 "

The Composing Room.—The work of the hand compositor or typesetter should not involve any danger except that which comes from handling lead type. That risk is inherent in the trade and cannot be eliminated, but if this were the only risk it would be possible to protect him fully from all danger of chronic lead poisoning simply by providing him with ample washing facilities. If, then, he developed signs of lead absorption we could assume that he was eating his lunch with unwashed hands or handling his chewing tobacco with unwashed hands and that he had only himself to blame. The case is, however, not nearly so simple as that. The typesetter may be a man of scrupulously cleanly habits and he may yet be subject to poisoning from minute quantities of lead in the course of his work because there is lead dust in the room where he works or because he has to blow out old type cases or work near a melting pot or a pile of lead dross.

Pannwitz (5), who wrote a very thorough study of the printing trade in Germany, says that the chief evils in the typesetters' trade are all preventable. They are the lack of space, overcrowding, insufficient cleanliness, insufficient ventilation, an abundant production of dust. If the composing room is kept clean and well aired

and if nothing is carried on there but hand composition then there should be no more risk in health for a typesetter of good personal habits than for any other worker at an indoor and mentally exacting trade. The type cases should never be blown out with a bellows or a current of compressed air, but should be freed from dust with a vacuum cleaner. A wire screen laid over the type will prevent the suction from drawing in the type. In the Royal Printing Office at The Hague a combined brush and suction pipe is used. This is a flat brush with stiff bristles with the opening of the pipe in the center of the brush. The operator presses the brush down on the type in the case and rubs it to and fro, stirring up the dust and brushing off the type, and the suction in the pipe carries the dust away.

The risks to the compositor are often unnecessarily increased by bringing other processes productive of lead dust and fumes into the composing room. In newspaper offices the linotypes are often here, as is the melting pot for old linotype metal. In a Philadelphia newspaper shop I found a melting pot in the composing room and two boys working at it, one gathering up and dumping the used type and scrap, the other shoveling it into the kettle through a feed door 18 inches square, from which fumes could be seen escaping. Placing the steam tables for the making of matrices in the composing room does not add to the danger but adds a good deal to the discomfort and is unfortunately very common. The heat and humidity caused by this work are great enough to require that it be done in a separate room.

Closed type cases are preferable to open because the type is kept free from dust and need not be blown out. It is a pity that most cabinets and frames for racks are built three or four inches from the floor instead of high enough to allow sweeping, or flush with the floor so that no dust can accumulate under them. As it is, a boy must go down on his hands and knees and use a brush, something that should not be allowed in shops where the dust may contain lead. Plates and type must be cleaned from time to time, usually with "mineral oil," *i.e.*, petroleum distillate which was found by McConnell (66), to be free from turpentine, benzene, phenol, anilin, and wood alcohol. Benzene is, however, sometimes used. So is a strong solution of lye, which as it dries leaves a thin coating of potash on the type unless it has been carefully washed off, and this is irritating to the fingers of the typesetter.

It must be remembered that the work of setting type and the other processes connected with it is rather exacting in itself and should be carried on in surroundings as favorable as possible. At the best, the compositor is working at an occupation which requires much standing in one position, a position which cramps his chest and favors an unequal development of the two sides of the body; he has far too little muscular exercise and a disproportionate amount

of nervous tension and eye strain. For these reasons a meticulous attention to sanitary details is justified in printing shops.

Linotype Machines.—The linotype is a machine which casts a solid line of type known as a "slug." The operator presses the keys on the keyboard and one brass matrix after another passes through a channel from a portable magazine to an assembler where space bands mechanically wedge the line tight. The molten lead is then forced in a jet from the pot by a plunger, and fills the characters which are countersunk in the sides of the brass matrices. The lead hardens almost immediately and a line of type has been cast. Then the space bands separate, the matrices are automatically distributed to their proper receptacles, and the finished slug is deposited on a specially provided galley.

For our purpose the important features connected with the linotype are the melting pot with its heating apparatus and the lead scrap which falls from the machine while it is in use. The method of cleaning the machine and of cleaning the plunger is important also. Then it is a matter of great interest to know whether any device is installed to carry off fumes generated in heating the melting pots, and, if there is such a device, whether it is really efficient. Electric heating for linotype pots is now used in some newspaper plants, making exhaust ventilation unnecessary.

Dr. Phelps' experiments showed that no lead fumes are given off from molten lead at temperatures such as are found in the various processes of printing unless the lead is vigorously agitated. In linotype machine operation no such agitation takes place. The pot tips slightly and the plunger drops, but that is all. Except when dross is skimmed and dropped on the floor it is highly improbable that any detachment of lead oxid occurs in linotype work which could cause any appreciable contamination of the air.

To prove that there are no lead fumes from linotype pots is not to prove that work on these machines is without risk to health or even that there is no risk from lead poisoning. There are many sources of possible lead poisoning in machine composition as it is usually carried on, and it is not hard to find justification for the disappointment that was experienced when it was found that the introduction of mechanical typesetting and the displacement of handwork had not resulted in the abolition of lead poisoning as had been claimed.

There are many sources of lead dust in this work. While work is going on, lead in the form of cuttings and powder keeps falling to the floor and accumulates in a heap under the machines. Usually it lies there till the day's work or the night's work is over and then it is swept up and taken to the melting pot, but sometimes sweeping goes on while the operator is working. In any case men are continually passing to and fro, grinding this lead into dust and

tracking it over the floor, and the finer parts are lifted by drafts of air and can easily be wiped from the surface of the magazine.

In the Royal Printing establishment of The Hague there are twelve linotypes in one room, all provided with hoods and with artificial suction, but the best feature is a metal pan which is so shaped as to fit accurately around the standard of the machine so that it can catch all the fragments of lead. The floor is of yellow tiles and the bits of lead would show quite clearly on it, but at the time I visited it, the pans were well filled and no fragments of lead had fallen on the tiles. At the end of the day it is a very simple thing to lift these pans and carry them off to be emptied. In a few of the printing shops in this country metal pans have been placed under the machines, but the standards of American machines are so complicated that it would seem impossible to make a pan which would fit into the irregularities.

This is not the only source of lead dust in the linotype room. A feature that was spoken of in the description of the composing room as adding quite unnecessarily to the danger is found also in connection with the linotypes, and that is melting down linotype metal and casting the "biscuits" of lead in the same room with the machines, sometimes quite close to them. This may mean contamination of the air with lead oxid if the melting is done during working hours, and even if it is not, it means that great piles of lead scrap are allowed to lie on the floor and add to the danger from dust.

Other sources of possible lead poisoning for the linotype operator or for the machinist are found in the cleaning of the machine and of the plunger in the melting pot. In places where there are many machines a machinist has charge of keeping them in order and the operator has nothing to do except perhaps to feed in the lead "biscuits," but if there are only two or three or even four machines, each operator takes entire charge of his own and is therefore exposed to a good deal of lead dust.

To clean out the scraps of lead which scatter through the different parts of the machine some men use compressed air, while others blow out the scraps with a pair of bellows, but in any case there must be some brushing with a soft brush or wiping with cloths. Then there is the cleaning of the plunger, which is much dustier; for the plunger is covered, not with scraps of metal, but with a fine deposit of lead oxid, which can easily be seen in the form of a gray powder coming off in clouds when it is brushed. If one considers all these sources of possible contamination of the air by lead in the form of metallic dust, or still worse, oxid dust, it is easy to see that lead poisoning may still be a danger in linotype work even if there be no fumes from the molten metal in the pot.

In addition to the danger of lead poisoning, the operator is ex-

posed in many instances to the effects of carbon monoxid from the gas burners under the melting pots. The presence of even small quantities of this poisonous gas in the air of a printing shop gives rise to such symptoms as headache, feeling of lassitude or languor, slowing of mental powers, breathlessness on exertion, drowsiness by day and insomnia by night. That it is the gas which causes these symptoms in linotypists is seen by the prompt disappearance of the headache and drowsiness in the open air and by the rapid improvement experienced by the men when proper measures are installed for carrying off the fumes from the burners. For instance, in a Chicago newspaper composing room there are thirty machines. The building is low and the window ventilation not very extensive, but the air is excellent because over each machine is a pipe with a strong up-draft caused by a fan in the chimney to which the pipes run. The foreman in this room told me that the men had felt at once an improvement in their health and in their capacity for work when this system was installed and that each time the fan had got out of order they had begun to complain of bad air within an hour's time. Now the effects of lead fumes, in the quantity that could be given off from small linotype pots, would come on very slowly and would not be perceived by the men for weeks, or more probably months, and the relief from such fumes after the installation of an exhaust system could not possibly be felt with such promptness and certainty as was true in this case and as was true in several other instances related to me. What the linotype operator is conscious of is the effect of the gas from the burner, not of lead fumes.

Hahn, who refuses to believe that there are fumes of lead from linotype pots, still insists that the gases from the heating apparatus must be carried off and, therefore, that these machines must always be furnished with pipes and an exhaust. Roth (7) also speaks of the danger of poisonous gases from heating the lead with illuminating gas, as do Legge and Goadby (8).

It follows, then, that all machines should be provided with an exhaust system to carry off gas fumes; for they are a menace to the health of the operator. This has been demanded by the men themselves in many instances, but not so often as one would expect. Many a composing room is devoid of any protection of this kind, even though every operator in it is a member of the union. Apparently the health committees of the different locals vary a good deal in their activity in this respect. St. Louis is the only one of the seven cities visited where at the time of this investigation all the linotypes were provided with pipes to carry off the gas. The Department of Labor of New Jersey has insisted on this precaution in all printing plants in that state.

We have spoken of the danger of lead dust in cleaning the ma-

chines and especially the plungers. When the care of only one linotype machine is involved, the risk is slight; but when there are many, the man who has this work in charge runs a decided risk, a risk which is sometimes recognized by machinists but perhaps more often ignored or dismissed with contempt. Such work is very commonly given over to the machinist's helper, who may be a boy. He may have to clean plungers every day or only once a week. There is the greatest difference in this respect in the different shops, some cleaning very often, others less than once a week. Those who use automatic feeders for the pots say that very little plunger cleaning is necessary; for the lead in the pot is kept at the same level all the time, and the dross on the surface does not sink down to the level of the plunger, as it often does when the operator has to do the feeding and delays too long. It is coming in contact with the dross that clogs the plunger and necessitates frequent cleaning. In one of the Chicago newspaper plants plungers are cleaned each day, twelve of them in a half hour, while in another plant in the same city cleaning is done only once a week.

The usual method is to take the plunger out and, without letting it cool off, for that would mean that time would be lost in heating it again, to brush it off briskly with a wire brush. When this is done a very distinct cloud of gray dust comes off, and this is a finely divided suboxid of lead, which is easily breathed in and is one of the most dangerous of the lead compounds. The only safe way to clean plungers is in a closed box worked from the outside. Such mechanical cleaners are obtainable from printers' supply houses and are said to be saving of labor, as well as sanitary. Certainly they do prevent dust.

Monotype Casting.—The monotype machine has the keyboard quite separate from the caster; indeed, the two kinds of work are not usually done in the same room. Perforated strips of paper are produced by the keyboard machine and these are fed into the caster and serve as molds for casting the type. The first process need not be considered, since it is essentially the same thing as typewriting, but monotype casting is generally regarded as fairly hazardous work. The temperature of the melting pot of a monotype machine is always decidedly higher than that of a linotype pot, running from 500° F. in one Baltimore newspaper up to 850° F., which was stated to be the temperature in a St. Louis job shop. The difference depends largely on the different alloys used. There is very little agitation of the metal in the monotype pots and it is unlikely that lead oxid is given off except in skimming dross.

Gas is almost always used for heating, and all that has been said in the section on linotype work with reference to the evils of gas fumes and the necessity of carrying them away by a hood and exhaust system applies also to monotype casting machines. As is true of

the linotype machines, lead scrap is constantly falling from monotype casters on to the floor and must be swept up and remelted. However, as a usual thing the casting is carried on in a separate room and whatever the risks they are confined to the few men who do the actual work. As a rule, also, the room is well placed, along the outer wall with plenty of window space. It is really the exception to find a dark, ill-ventilated, ill-kept monotype casting room. The substitution of electric heating for gas heating of monotype casting pots marks a great improvement; for it means that gas fumes are abolished and that there is much less heat given off from the pots.

Stereotyping.—The evils to be avoided in stereotyping are: the fumes which arise when old plates are being melted down or “burned off,” as the process is usually called, which fumes come from the ink and contain acrolein;* the lead oxid which, as Dr. Phelps’ experiments (pp. 141-142) show, may be given off if the temperature is high and the metal is agitated; the dust caused by trimming and routing the plates; the heat from the kettles.

The work of stereotyping is as a rule badly housed and imperfectly safeguarded, although the usual habit of placing the foundry in the basement does not always work out badly; for there are some basement foundries so well ventilated by good drafts of air down shafts and by suction fans in windows or air shafts that conditions in them are actually better than in others situated above the ground.

Occasionally, it is not the stereotyping which adds unnecessary danger to other less dangerous work, but vice versa; as, for instance, in a Chicago foundry, where a cupel furnace for refining dross has been installed in a stereotyping room. Lead must be heated to a far higher temperature in such a drossing furnace than in the kettles for stereotype metal, and the lead usually runs out hot enough to give off visible fumes of oxid. In the largest printing plant in Washington the work of stereotyping is made not only unnecessarily disagreeable but hazardous by the proximity of the room for remelting and mixing metals, which is situated just beside the foundry. Many thousand pounds of used type are melted down here every day, with the evolution of such thick clouds of acrolein as sometimes to overcome the stereotypers working nearest to the door.

The lead in stereotype kettles is usually kept at about 700° to 750° F., but it may be as low as 600° or as high as 800° F. In five places this last temperature was found, and the statement was made several times by foremen that the heat might run up pretty high, “even to fuming point, if it is not watched.” Since the lead is being continually agitated by ladling or pumping or by skimming off dross, it follows that there should be an exhaust system to carry off the fumes, and this is generally recognized as necessary for the

* See page 432.

dense smoke which rises when ink-covered plates are melted down, even if the men do not realize the necessity for also carrying off the less perceptible but dangerous lead oxid dust. The majority of stereotype kettles are protected by some form of hood. Sometimes it really incloses the top, but in that case there must be a fairly wide door for feeding and for lalling out the metal, and naturally this is left wide open, except, perhaps, when the smoke is bad at the beginning of melting down. If the new autoplate attachments have been installed, the hood cannot come down within one and one-half or two feet of the edge of the kettle; for the apparatus prevents it, so there is in this case a wide area for the escape of fumes. In the course of my investigation I did not find one stereotype kettle from which fumes could not be seen to escape, even from under a hood, provided the surface of the lead was well stirred up. Therefore it may be true, as some foremen claim, that it is better to discard a hood altogether and to depend instead on a strong suction fan in the wall as near as possible to the pot. In the best newspaper building in Boston this has been done, and it is said that the room is in consequence cooler and the air better; for the hood used to catch and hold the heat.

In addition to lead oxid from the molten metal, another source of air contamination in these foundries is the lead dust. Routing machines are very often placed here, and even if they are in another room the scrap from routing is gathered up and dumped on the floor near the stereotype pot to be remelted. Then there are the shavings and scraps from the trimming and shaving of the plates and there are the dross skimmings which are almost invariably thrown on the floor and have to be gathered up later for the drossing kettle. Sometimes every bit of the floor of the foundry is thick with lead dust, and it is swept up and thrown about as carelessly as if it were sand.

The discomfort of work is increased for the stereotypers when the steam tables for matrices are placed here, or when electrotyping, with its black lead and blasts of steam, is carried on in the same room.

In the course of the inquiry among printers, made by the Illinois Commission on Occupational Diseases (in 1910), one of the investigators, Dr. Emery R. Hayhurst (9), now of the Ohio State Board of Health, examined 57 linotypists and found two of them probably "leaded," which would represent a proportion of 3.5 per cent; while of 79 stereotypers whom he examined, six or 7.6 per cent, showed evidence of plumbism. These men had all worked more than ten years, and two had slight palsy of the wrists.

Electrotyping.—In electrotyping, a wax mold (usually not of beeswax but of ozokerite, a waxlike mineral) is made from a page of composed type or an engraved plate. This is then covered with

black lead (graphite), either dry or suspended in liquid, in order to render the wax conductive to electricity, and is suspended in a bath of sulphate of copper through which passes an electric current which causes the deposit on this wax mold of a thin coating of copper. The wax is removed and the copper shell is mounted on a lead back.

The important features in this work are the pot in which the lead is heated, the hot pans on which the process of backing is carried out, the trimming and routing of the plate and, in some instances, the use of wood alcohol to clean the plates and favor the deposit of the copper.

The lead for the backing of plates is melted in an open pot and poured out on heated metal pans. Since it is a simple thing to cool the lead down to just the right temperature in these pans, it does not matter if the lead in the pot is allowed to run up to a fairly high temperature. Usually about 650° to 700° F. is the point aimed at, but foremen admit that it is not closely watched, that 850° F. is not unusual, and that it may even go up to "fuming point."

The copper shell is washed off with soldering fluid, then covered on the reverse side with thin lead foil, and laid face down on the surface of the lead on the backing pan, the heat of which melts the foil. Then the plate is removed to a cooling table and a ladle of molten lead is poured over it to back it. It is cooled, sawed or shaved to the proper height, hammered to the right level, the edges are beveled and the superfluous metal is removed by routing. A routing machine has a tiny chisel which cuts away the lead from the parts of the plate where it is not wanted, sending the fragments flying far and wide. The chisel is grooved in such a way as to give the lead chips a downward direction on the whole, so that they are not likely to fly into the operator's eyes, but the possibility of this is great enough to make the use of goggles very desirable.

There are two chief dangers in an electrotype foundry—lead dust and lead oxid from the pot and the backing tables. As is true in all departments of the printing trade, old lead is remelted and the metal used a second time, and when these ink-covered plates are melted down there is the same evolution of acrolein fumes as is found in linotype melting pots and stereotype pots. As to the question concerning the lead fumes from these pots, Dr. Phelps' experiments show that when the temperature reaches 450° to 520° C. (842° to 968° F.) and the lead is stirred or skimmed or ladled, or new lead is added, the coating of lead oxid is detached and rises into the air immediately surrounding the pot. This means that some method should always be adopted to carry off fumes, either by installing a hood with a strong up-draft or by placing a fan in the outer wall close to the kettle. As a usual thing there is no hood over the pot, and when there is, it is rarely adequate to serve its

purpose. Often it is adjustable and is lowered only when the metal is being melted down, to prevent the escape of the disagreeable smoke, but is raised again just at the time when the danger from lead begins. If the hood is stationary, it is likely to be placed too high to be of much use, especially when the vent is narrow and the air exhaust weak. This danger of fumes, not only from the pot but also from the backing table, is recognized in all the better-class plants. The largest foundry in Philadelphia has placed hoods over both backing table and pot, the hood for the latter being adjustable and lowered during melting-down.

In addition to the fumes there is more or less lead scrap in an electrotype foundry, sometimes a large quantity. This collects around the routing machines, even when they are enclosed in walls of wire net; for the smaller fragments make their way through the net. There are also shavings from sawing and beveling the plates, and there is a good deal of lead splashed on the floor when the men are backing plates, and there is often dross, also, if it is not dropped into a special receptacle. All this scattering of lead is quite unnecessary. I have seen foundries, notably a model one in Chicago and another in St. Louis, where no lead is permitted to fall on the floor and remain there, but these are exceptions; for usually no care at all is taken. Another source of lead fumes is the solder which is used to fasten together parts of plates which have had to be sawed apart to make corrections. This is ordinary solder used in the ordinary way with a gas flame. In very large foundries the sticks of solder are made on the premises by ladling the metal into molds. A certain amount of hand finishing may also be done in connection with electrotyping, such as scraping leads and "mortising," *i.e.*, filing.

Black leading is dirty work, but it is perfectly harmless; for the black lead is only carbon. It is very light and flies everywhere, darkening walls and ceilings, and settling on the windows, and this may be one reason why electrotype foundries are so often dirty, neglected places. The effort to keep them clean is too great, apparently, and they are surrendered to the dirt that is looked upon as inevitable. The heat in a foundry is usually great enough to be very disagreeable and in many places the discomfort of the workmen is increased by the use of a blast of steam to clean the plates. Hayhurst found five electrotypers among twenty-one cases of lead poisoning in the typographical trade in Chicago. All had worked more than ten years and four of the five had weakness of the wrists.

Pressroom.—The work in the pressroom has many elements of discomfort, but there is no risk of lead poisoning unless the stereotype foundry is so placed as to send fumes into the pressroom. These rooms are often poorly ventilated and the excuse is given

that a current of air is bad for the ink. They are also dirty, but the dirt is of a harmless kind and the floor is usually so oily as to be dust-free. The composition of the ink is a matter of some importance and so is the method of cleaning press rollers.

There is frequent complaint by pressmen of the irritating action of ink on the skin. McConnell investigated this for the Public Health Service in 1921, and found that eleven specimens of printers' inks caused no irritation when applied to the unbroken skin, although they seemed to delay healing if applied to cuts and scratches. Brown and green inks had the most pronounced effect, black had the least. He attributes the dermatoses of printers to the methods used for removal of the ink, especially if the man's skin is dry. If the ink is poor in linseed oil and the skin is poor in natural fats the irritation will produce a dermatosis for in that case the skin may be compared to a blotting paper, readily absorbing the ink. Then there is much more difficulty in removing it, and the man scrubs vigorously, using sandsoap or pumice or a stiff nail brush, all of which remove the cells of the outer skin, allow the ink to penetrate still more easily, and finally result in an eczema. He examined thirty-five cases of dermatosis and all were in men whose skin was wholly or partially devoid of natural oiliness. Cleaning plates with benzin increases the trouble. McConnell advises anointing the skin with equal parts of lanolin and olive oil before work, washing with sawdust wet with liquid soap and warm water, and applying a calamine paint made with gelatin, glycerin and water.

It is interesting to note that McConnell found lead chromate in all except black inks.

Press rollers are made by boiling together glue and glycerin. They are cleaned usually with benzin or kerosene, and the men complain that the fumes are irritating if they use benzin, while kerosene or the heavier oils may cause acne on the hands and forearms. The really harmful roller washes, however, contain anilin oil or wood alcohol or carbon tetrachlorid.

Dross Recovery.—Newspaper plants and large job houses have of late years installed dross refining equipments to recover the lead from dross skimmings instead of selling it to junk dealers. Sometimes the dross is simply remelted and a small part of the lead recovered, the oxid being sold, but in several plants cupelling furnaces have been installed for the actual reduction of the oxid. This introduces a quite new danger into the printing industry and one with which the employers are usually not at all familiar so that the risks inherent in the work are not always recognized. Such departments should always be absolutely separate from the rest of the plant. The best arrangement I have seen is in a Chicago newspaper plant which has installed its furnace in a small iron shed on the roof.

Type Founding.—According to German and Austrian factory inspection reports, the founding of type is carried on in connection with printing in those countries and the rate of lead poisoning in the typographical trades is always decidedly increased by including the type founders and their women helpers. (See page 11.) In the United States, type founding is a separate business, carried on chiefly in three large establishments. There are, however, some book and job houses and a few newspaper offices that have small type founding machines of their own in addition to the monotype and linotype machines. These are essentially the same as the ones in the large foundries.

In the course of the inquiry made in 1916, I visited four foundries, three large and one small. The larger ones mixed their own alloys in kettles, the work involving all the familiar risks which attend feeding, drossing, and discharging lead kettles.

Two kinds of type casters are used in type foundries, the old Bruce machines which cast type requiring to be "finished" in various ways before it can be used, and the newer Barth machines, the type from which is already finished and ready for use. The Bruce casters have open lead pots, from 4 to 8 inches in diameter, and the temperature of the lead is said to run from 600° to 850° F. They are heated by gas. Barth casters have larger lead pots, about 11 inches in diameter at the top, and the lead is kept at about 750° to 800° F. They, too, are heated by gas. In none of the foundries were there any hoods either over the molten lead or to carry off gas fumes, yet in one large room no less than 75 Bruce casters and 250 Barth casters were found. The evil of gas fumes is the same as in connection with linotype work and the risk of lead fumes is greater; for the lead is kept at a higher temperature.

The feature always emphasized by foreigners writing on the danger of work in a type foundry is not, however, lead fumes so much as lead dust from the hand finishing of type. The type cast by the Bruce machine must go through various processes, all of which are productive of dust. First the "jet" must be broken off. This is a little projection of lead at one end, produced in casting. Then the broken surface on the edges of the type must be smoothed by rubbing on a file—this may be done by machine or by hand—and the pieces of type must be "set up," placed in a row along a stick with another stick fastened at right angles to hold them preparatory to "dressing" or grooving out the foot. There is also a machine for "kerning," smoothing type to make certain letters fit more closely side by side. Finally there is inspecting, assorting and packing.

By far the greater part of this work is done by women and girls. In one large foundry the filing and inspecting were done by men; the rest of the finishing employed some 200 women. In a smaller

one all the finishing was done by 20 women, and in a third, 7 men, 2 boys, and 24 women were employed.

Finishing is dusty work, and the dust that is produced is apt to be inhaled by the women, since the work requires close attention, and the women sit bent over their benches with their heads close to their machines or tools. The fine, gray powder can be seen on the benches, and the women clean it off with soft brushes. They also use pads of plush to hold the type, and these get full of lead dust and are shaken and beaten clean from time to time. The finishing is often carried on in the room where the casting machines are installed, with their gas fumes and, possibly, lead fumes.

The only cases of lead poisoning among women in the typographical trades which were discovered by the Illinois Occupational Disease Commission were among workers in this department of a type foundry. Four women, all employed in finishing type by hand for periods of from three and one-half to thirty-five years, were suffering from chronic plumbism. They, of course, represented less serious forms of lead poisoning, since they had been able to keep on working. There is a continually changing force of girls and women in this sort of work, the more susceptible quitting, the more resistant staying on.

The boys in American printing shops are not protected from the dangers incidental to or inherent in the trade. There are no rules formulated by the International Typographical Union against entrusting to apprentices work which involves exposure to lead fumes or dust. In most European countries where it is recognized that young people are more susceptible to lead poisoning, such rules are in force. In Germany, boys are not allowed to blow out type cases; in Norway, they must not sweep the floors; in Denmark, they are forbidden to work in the stereotype department. Both the Austrian and the French Governmental Reports recommend that no young person be allowed to do work which would bring him in contact with lead.

According to the Union rules in this country, the term of apprenticeship must be at least four years, but in some cities this is increased to five. The age at entrance is not specified and naturally follows more or less the child labor laws in different parts of the country. New York and Chicago insist on sixteen as the minimum age and the course in each of these cities covers five years. The planning of these apprentice training courses is left to the locals, but though the number of apprentices permitted varies in the different locals, it is always strictly limited, and consequently there are in all shops numbers of boys who may not be old enough to enter as apprentices or who are waiting for a vacancy, and meantime acting as floor boys or porters, and there are also boys who are simply working as they would in any shop without entering the trade as apprentices.

Union rules provide that copyholders and errand boys may not set or distribute type or break up forms, but they often do the sweeping and tend to the melting pot. Apprentices have their course more or less rigidly prescribed and are usually forbidden to work overtime or more than six days a week, but there is nothing to prevent their doing any sort of work in the composing room. Apparently the Union has no realization of the damage that may be done to these boys during their immature years; for in the course of my investigation in seven cities I saw boys actually at work in many occupations which should be forbidden to children. In newspaper shops boys were sweeping around the linotypes and gathering up lead scrap; one boy was down on his hands and knees brushing the scrap from around the very complicated standards of the machines. Boys were employed in cleaning linotype machines by blowing and brushing, and in cleaning linotype plungers with a metal brush. In almost all newspaper shops the gathering and dumping of scrap, feeding it into melting pots and casting "biscuits" for the linotypes, was entrusted to boys. Blowing out dusty type cases is recognized by all printers as a dangerous job, yet I saw it done by boys in four cities. There is usually in an electrotype foundry one boy to five or six men and they always do the sweeping around routers and kettles. On the other hand, boys are almost never seen in a stereotype foundry.

Among the one hundred printers examined by Dr. Ellis in Chicago, were two youths who showed evidence of lead poisoning. One was a machinist's helper who had worked only two months in a large shop, cleaning linotype machines and plungers. He had a lead line, anemia, digestive disturbances, constipation, headache, and disturbed sleep. The other was sawing and trimming castings. He also had a lead line, anemia, headache, abdominal pain, attacks of dizziness, and constipation.

Women are accepted as members of the Typographical Union on exactly the same terms as men. They must go through the same apprenticeship and after becoming journeymen they have the same hours and receive the same pay as men. They are found in large numbers as proofreaders and are usually the operators on the monotype keyboard. In Union shops these women must be practical printers who have gone through their apprenticeship. As compositors and linotypists they are not numerous. In the course of my investigation, I saw only 14 women linotypists out of a total of 1,532 operators and only 103 hand compositors out of a total of about 3,800. Of these 117 women, 86 were in non-union or open shops.

As is true of women's work in all trades there is a wide difference of opinion as to whether it should be permitted in the printing trade, and at different meetings of the International Association for Labor

Legislation the subject has come up for discussion. The Italians, under Carozzi (10) and Devoto, have led the campaign against employing women in the printing trades, on the ground of their greater susceptibility to lead poisoning and the disastrous effect of lead poisoning on a woman's offspring. The Austrians, also, were in favor of forbidding women to work at any occupation in printing which involved contact with lead, and regulations now in force in Austria contain this provision. The British, on the other hand, have held that it was entirely possible to do away with the danger of lead poisoning in the printing trade and that efforts should be directed toward that rather than toward shutting women out of an industry in which they had long been employed and which is in many ways suited to their powers.

In all European countries the printers' trade has long been considered an occupation unhealthful beyond the average and this belief is confirmed by statistics which show an abnormally high sickness rate and death rate for printers as compared with all occupied males. In the United States, also, the printers' trade is productive of more illness than would be looked for in an industry where wages are high, hours not long, and where there is no great contamination of the air, or exposure to excessive heat or cold, or over-exertion. American printers suffer far more from tuberculosis than do working men in general.

The sickness among printers is in Europe attributed partly to the fact that the industry is recruited from the less robust, less sturdily developed boys who reach working age, because they think it is a trade that does not require much muscular strength. Pannwitz lays great stress on this feature and brings statistics to his aid to show what a startlingly small percentage of the men in the typographical trades are fit for military service. The average number of men accepted for service out of 55 districts during three years, 1889 to 1891, was 427.3 out of 1,000 employed in all trades, but only 238.1 for the printing trades. Rejections were based chiefly on the ground of weak physical constitution, poor development of skeleton and muscles, and weakness of vision. Pannwitz concludes that not only is there an unusual proportion of weaklings in this industry, but the sanitary conditions under which they work are more productive of illness than the work itself warrants. This is said by Layet (11) to be true of the industry in France also, and the Austrian government report makes the same statement for Austria.

No one casually observing American printers would gain the impression that this is an industry attracting weaklings chiefly. Their general appearance is that of well developed men in average health, yet the figures of the Prudential Insurance Company show that 589 printers insured in that company averaged somewhat lower

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in height and weight than the general average for all wage earning males. The figures are as follows:

Average weight at entry, Printers 149 lbs.; all others, 157 lbs.

Average height at entry, Printers 67.7 inches; all others 68.1 inches.

Relative weight at entry (pounds per inch), Printers 2.21; all others 2.3.

Tuberculosis is the great enemy of the printer. Wherever the death rate has been found to be high the cause has been a disproportionately large number of deaths from pulmonary tuberculosis. This is found in the records of all countries. The Registrar General for England and Wales gives for the year 1908 the death rate from tuberculosis among printers as 31 per cent of all deaths, while for occupied males it is only 18.9 per cent. In Holland, DeVooys (12) finds the tuberculosis death rate of printers to be higher than that of painters—another lead trade—or of shoemakers—another sedentary, indoor, exacting trade. In the early age groups, from 18 to 35 years, Dutch printers have more than double the death rate from tuberculosis of all occupied males.

Bertillon (13) in a statistical study made in 1891 said that Swiss printers had twice as high a death rate from tuberculosis in every age group as the population in general. Carozzi gives figures for the city of Milan, which is one of the centers of the printing trade of Italy, and the general population of Italy. In 1909 the per cent of deaths due to tuberculosis was 12.23 for the general population of Italy, 14.13 for the population of Milan, and 35.93 for the typographical trade of Milan. In Germany all of the writers who have taken the printing trade as their subject say that tuberculosis is very prevalent among printers, but this is much more evident in the earlier reports than in the later. During the period 1857 to 1889, Albrecht (14) found that 49.43 per cent of all deaths were from tuberculosis; from 1889 to 1891, Sommerfeld (15) gave the proportion as 44.44 per cent; from 1901 to 1907, Hahn gave 37.7 per cent; and for 1903 to 1905 Silberstein (16) gave 37.33 per cent. This improvement is attributed to the passage in 1897 of a law regulating sanitary conditions in printing shops.

The comparison of the per cent of deaths due to tuberculosis among members of the International Typographical Union and among men in the registration area of the United States shows a large excess among the printers. The decline in recent years, however, has been much greater in the Union than in the country as a whole. Thus among males in the registration area in 1900 the per cent of total deaths due to pulmonary tuberculosis was 15.2 and in 1912 to 1914 it had fallen to 12.7. The figures for the Typographical Union are much higher, but the fall is also greater. From 1898 to 1902, it was 31.4 per cent, and in the period from 1913 to 1915 it had fallen to 17.9 per cent.

A careful study of the causes of death as given by the Union records from 1893 to 1915 shows that what has happened in recent years is a lengthening of life and, as an increasing proportion of the printers have reached old age, they have in increasing numbers become subject to and died of diseases of old age—heart disease, apoplexy, paralysis, Bright's disease, and nephritis.

The effect of lead in causing deaths from heart disease, apoplexy and paralysis and from kidney disease has been the subject of some controversy. The experience of the International Typographical Union seems to show that something in the printing trade tends to produce an excess of early deaths from these diseases. Among white males in the registration area only 18.6 per cent of all the deaths from heart disease occurred under 45 years of age, among printers, 26 per cent. The deaths from apoplexy and paralysis show an even greater excess in early life, only 9.1 per cent of the deaths from these causes occurring under 45 years among males in general, but 20.4 per cent among the printers. The excess of deaths from Bright's disease and nephritis develops somewhat later, in the next 10 year group, 45 to 54 years, where we find the percentage for males in the registration area to be 19.9 and for members of the Typographical Union 30.3.

The diagnosis of lead poisoning is especially difficult in this industry because only in rare instances are the symptoms typical. The lead line is usually absent, especially if the teeth are well cared for. There may be no positive symptoms of lead poisoning except anemia, and the abnormal staining or stippling of the red corpuscles may be absent.

We have already referred to the examinations made of two hundred printers in Chicago and Boston by Drs. Palmer and Ellis who worked independently but used the same method. Their report was made out with great caution; for they tried not to exaggerate the importance of lead as a cause of disease among the men. Probably no two medical men would interpret in exactly the same way the symptoms or signs of disease presented by any given group of printers; for while one would look with suspicion upon any digestive or nervous or arthritic disorder as possibly caused by lead, the other might attribute it to a fatiguing indoor occupation or to errors in hygiene or to alcoholism.

The results obtained by Dr. Palmer and Dr. Ellis, working in two different cities, were surprisingly similar. Forty-five of the 100 Boston printers and 48 of the Chicago printers were found to be quite free from disease, the remaining 107 suffered from various forms of ill health. One-third of the Chicago printers admitted freely that they used alcohol to excess and occasionally became intoxicated, and only 29 were total abstainers. Dr. Ellis considered it reasonable to suppose that the nervous symptoms complained of

by this type of men were largely due to alcoholism. In Boston 35 of the men claimed to be total abstainers and only four admitted excessive use of alcohol.

A lead line on the gums was found in only two of the 200 men, and only one had stippling of the red blood cells; yet there were 21 who had been treated by physicians for lead poisoning and in 18 of these the diagnosis seemed to have been correct, since the men still showed evidences of chronic plumbism. This makes a rate of 9 per cent of lead poisoning among the 200 printers. Four more men had symptoms and history highly suggestive of the same diagnosis, and 10 men presented symptoms which would in the absence of alcoholism be strongly suggestive of lead poisoning, viz., gastric distress, morning vomiting, foul taste, foul breath, constipation with occasional diarrhea, pain in the abdomen, pains in joints, or muscular cramps, tremor of the hands, weakness of grip, premature aging. Such symptoms may, however, be caused by the excessive use of alcohol, and as the ten men were all heavy drinkers, no positive diagnosis could be made in their case.

Among the 107 men who had some disturbance of health, the most important symptoms were the following:

25 men looked older than their age.

25 men had sclerosis of the radial arteries, but only four of them were under 50 years of age.

57 had a blood pressure of over 140 mm., and of these 30 were under 50 years of age as follows: 20 to 29 years, 7; 30 to 39 years, 10; 40 to 49 years, 13.

7 men had valvular heart disease (mitral insufficiency, compensated).

4 men had enlargement and increased consistency of the liver.

10 men had tremors of the hands.

24 men had a slight degree of anemia, hemoglobin between 70 and 75 per cent.

Tested with a dynamometer the general average for the right hand among the Boston printers was 112, while the general average of non-printers tested with the same instrument was 129. In Chicago, the average for printers was 97, for non-printers 120. Three cases showed a loss of power in the extensors of wrists and fingers and one of them gave a history of typical wrist drop following an attack of lead colic. A fourth, who also gave a history of lead poisoning, had complete extensor palsy at the time.

The most striking thing in the examination was the absence of pulmonary tuberculosis. Only one case, an arrested case, was found among 100 Chicago printers and none at all among the Boston men. The explanation seems to be that these men were all volunteers and that a certain selective action was exerted by the men themselves; for those who suspected that they had tuberculosis shrank from submitting to an examination.

The reason for the excessive amount of pulmonary tuberculosis among printers has never been clear. That it falls in consequence of measures which lessen the exposure to lead fumes and dust, is plain. Hahn says that lead and tuberculosis in this trade go hand in hand, and it is usually assumed that lead lowers the resistance of the body to tubercular infection.* Yet why should this be so strikingly evident in the printers' trade where the exposure to lead is slight, and not in lead smelting or paint grinding or storage battery work, or in any other of the really dangerous lead trades? The statistics of the Metropolitan Insurance Company for 1917 show that printers have a higher death rate from tuberculosis of the lungs, and death occurs at an earlier age than is true of workers in non-metallic lead. The figures for all ages are: for printers, 34.1 per cent of deaths due to tuberculosis; for painters, varnishers, etc., 21.9 per cent. The average age at death is 33.5 years for the printers, 39.9 for the painters. Another class of men exposed to lead in metallic form are plumbers and gas and steam fitters. These men also suffer more from tuberculosis of the lungs than the painters; their rate is 31.6 per cent and they die at an earlier age, 35.1 years. Some ten years ago Carozzi in an exhaustive study of the printing trade of northern Italy discussed this question and suggested that there must be something in the action of metallic lead when inhaled which is different from the action of lead compounds, but his suggestion was never followed up until recently when Fine (17), an assistant of W. O. Fenn at Harvard, undertook to examine the behavior of phagocytes toward different forms of lead, using the technique which was elaborated by Fenn in his studies of the phagocytosis of carbon and quartz particles. Fine discovered two facts of great significance in this respect. In the first place, metallic lead dust is ingested by phagocytes far more slowly than carbon particles or even than quartz particles, and more slowly than particles of white lead, basic carbonate. In the second place, the metallic lead under the influence of atmospheric air and moisture changes in part to the basic carbonate and phagocytes which have been exposed to the action of this basic carbonate are less able to take up particles of any kind than before. It appears, then, that metallic lead dust in the lungs is not phagocytized except with extraordinary difficulty, even greater than is the case with quartz dust, and we may assume that in consequence a fibrotic process is set up by the collections of minute quantities of such dust and these fibrotic areas are later invaded by the tubercle bacillus.

* Roos of the British Factory Inspection Service found that the amount of free silica in the dust of printing shops was very small, a negligible quantity. (C. B. Roos, *J. I. H.*, 1922, III, 257.)

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CHAPTER 12

THE WHITE AND RED LEAD INDUSTRY. STORAGE BATTERIES

THE WHITE AND RED LEAD INDUSTRY

THE white and red lead industry is carried on in Brooklyn, Staten Island, N. Y.; Perth Amboy, N. J.; Philadelphia, Pittsburgh, and Kensington, Pa.; Detroit, Mich.; Cincinnati, O.; Chicago, and E. St. Louis, Ill.; St. Louis and Joplin, Mo.; and Selby, Cal. In European countries the roasting of oxids to make red lead and litharge is usually carried on in smelters, but in the United States it is only in Joplin that this work is done in connection with smelting; the other plants either roast oxids only or make white lead as well.

The processes used in making white lead in the United States are four: the Old Dutch, the Carter, the Matheson, and the Mild, the two latter being used in only one factory each. For the Old Dutch process, the lead is cast in thin discs called buckles and these are packed in earthenware pots with a little acetic acid at the bottom. The pots are placed in rows on a bed of spent tan bark, planks are laid over them, another layer of tan bark, more pots, and so on till a "stack" has been built up, sometimes twenty feet high. The lead is called blue lead and the work is known as stacking or making the blue bed. It is quite free from the danger of dust if only fresh blue buckles are used, but very often scraps which were left uncorroded and have white lead clinging to them are mixed with these fresh buckles so that it is never safe to assume that the work of stacking does not involve any contact with white lead. The work in the casting room is, like all lead casting, free from risk provided simple precautions are taken and provided dusty scrap from poor corrosions is not used to charge the lead pot.

Corrosion, as it is called, the conversion of metallic lead to the white basic carbonate, is effected by the fermentation of the tan bark which produces carbon dioxid and heat to volatilize the acetic acid. About one hundred days are required for the reaction, and then comes the process of stack stripping or stripping the white beds or discharging the stack. This is admittedly as dangerous work as any in a corroding plant. In Great Britain and in all European countries except Belgium, the white lead powder is separated from

the inner unchanged core of metallic lead by washing it in great troughs of running water. This makes it possible to sprinkle with water each layer of white lead pots as it is uncovered in discharging a stack and according to law in these countries water must be used to keep down the dust, but in the United States and in Belgium dry separation is used, crushing and screening with a discharge of white lead powder at one end and dusty fragments of metallic lead at the other. The stacks cannot be sprinkled and the stack stripper must lift each pot filled to the brim with flaky white lead and dump it into a truck, pounding the pot to get rid of the last fragment. Ten years ago, when I first investigated this industry, stack stripping was such dangerous work that many foremen would not employ their own hands on the job but brought in a gang of casual laborers and discharged them when the stack had been stripped. The very difficult problem of dust removal has been solved apparently as well as possible by the National Lead Company which has devised a covered truck with two openings in the top. One is for the large exhaust pipe, long and flexible, which allows the truck to be moved from place to place in the stack. The other is just large enough to allow the pot of white lead to be emptied. The dust produced is sucked into the truck and into the exhaust pipe.

The dump to the separator is a dangerous spot and in good plants dumping is effected mechanically and under an exhaust. The lead powder from the separator goes at once through series of washing tubs and then it may be ground in so-called "chasers" with oil gradually displacing the water. This is called pulp lead. Some of it is dried, packed and sold to the trade and the rest is dried and ground in oil.

The dry pan room used to be as great a source of lead poisoning as the stacks, sometimes even greater; for the lead powder was simply shoveled from the great open pans and dumped into chaser or barrel packer. Now, however, in all but a few backward plants the dry pans are completely enclosed and in order to empty them the workman has simply to open a narrow door, insert a long handled pole and draw the white lead toward him till it falls on a traveling worm running along the inside of the drying chamber. The man stands outside and there is a strong exhaust sucking air in and carrying the dust away from the opening through which he works. The white lead is then mechanically conveyed to the oil chasers or the barrel packers.

The Carter process is coming into increasing use in the United States as tan bark is increasingly hard to get. It is a quick process which depends on the same reactions as the Old Dutch but atomizes the lead so that it can be acted on far more quickly. This blue lead powder is charged into great revolving cylinders where it is sprayed with acetic acid and vapors of carbon dioxid. The process

is undergoing development all the time and less and less hand work is required. This is its great advantage, the disadvantage is the fact that throughout the whole process the men are working with lead in the form of a fine powder.

The Matheson process is a precipitation process, safer than the Old Dutch, because work in the corroding stacks is replaced by precipitation of white lead in water. The Mild is also a wet process, atomized lead being treated with air and water and carbon dioxide. However, in both of them drying, grinding and packing have to be done with the same precautions as are needed in the Carter and Old Dutch processes.

In roasting oxids, pig lead is roasted to litharge and a second roasting produces red lead. Both of these oxids are very light and fly about readily if handled in the open. It is possible, as I have seen in two or three plants in the United States and in a large German plant, to carry on practically all of the processes mechanically so that there is no escape of dust and one would not suspect from the color of floor and walls that red lead was being made. Unfortunately this is the exception and usually the furnace room and still more the grinding, screening and packing rooms are stained scarlet or the pinkish buff color which litharge gives. In a modern plant the furnaces are mechanically charged, rabbled and discharged, the oxids fall into a car pushed under the furnace and the car is allowed to stand till it cools off before it is drawn out. Exhausts over the dumps and closely covered grinders and screens prevent the escape of dust. In a carelessly managed plant there is often not one spot free from fumes or dust.

The white lead industry has undergone enormous improvement during the past ten years, not only with regard to construction and operation but also with regard to the personal care of the men. Many plants now measure up in this respect to the best in Great Britain and Germany, but the American method is still accompanied by more danger than foreign methods, except the Belgian, and lead poisoning cannot be regarded as anything but a very present danger in a white lead plant. The cases of encephalopathy which go to the hospitals of Philadelphia, Chicago, and St. Louis are still more likely to come from the white lead works than from any other trade, for when poisoning does occur in a white lead worker it is usually of the acute kind, either colic or convulsions or both.

The general impression obtains that less lead is used in paint nowadays than formerly, and while this is true of red lead paint it seems not to be true of white lead. Interviews with white lead producers have convinced me that there has been an increased production of white lead since the war and the painting trade is still the largest consumer, with potteries coming next. The increase in the demand for the oxids, red lead and litharge, is much greater, for the

increased manufacture of motor cars means more rubber and litharge is still holding its place as a compound of rubber, and it also means a much greater production of storage batteries which require both red lead and litharge. The introduction of radio sets brings about a new demand for storage batteries. Unfortunately reforms in the production of the oxids are not as conspicuous as they are in the production of white lead, and it is probable that an investigation of this industry would show, as it did in 1910, that the rate of poisoning is higher among the oxid men than among the white lead men, although red lead and litharge are not as soluble in gastric juice as is the basic carbonate.

The chief uses for red lead and orange mineral are the following:

- Storage batteries.
- Enameling sanitary ware.
- Manufacture of paint.
- Manufacture of varnish.
- Manufacture of leaded glass.
- Manufacture of printing inks.
- Manufacture of linoleum.
- Glazes for tiles and terra cotta.

The chief uses of litharge are:

- Storage batteries.
- Rubber.
- Manufacture of varnish and driers.
- Color making.
- Glass, especially high grade optical glass.
- Enameling.
- Making arsenate of lead.
- Oil and grease refining.
- Lead and glycerin cements.

STORAGE BATTERIES

The making of storage batteries, or electric accumulators as they are called in every country except our own, is a dangerous lead trade strictly regulated by the government in Great Britain and all European countries.* There are six large factories in the United States, situated in Philadelphia, which has two; in Niagara and Depew, N. Y.; in Cleveland; and in Indianapolis. There are a great many smaller plants scattered throughout the country, and many automobile factories now have their own storage battery departments. There are also establishments where assem-

* The report of the British Factory Inspection Department for 1919 contains the statement that the trade that now produces the greatest proportion of lead poisoning is not, as formerly, the making of white lead or glazing pottery or painting vehicles, but making "electric accumulators."

bling is done and old batteries are re-assembled and re-charged, especially for railway cars.

A storage battery is a collection of secondary cells or accumulators which when once charged by an electric current may be used for some time as the source of electricity. The original type of storage battery, known as the Planté, consists of lead plates which are usually perforated or corrugated to offer a larger surface for the chemical action of the charging current. The Faure cell was constructed with the purpose of hastening these chemical changes. Faure plates are covered with a paste of lead oxids, the positive plate with red lead or a mixture of red lead and litharge, rarely with pure litharge, and the negative, usually with litharge. Sometimes a Faure negative is paired with a Planté positive plate. Both Planté and Faure plates are "formed" by the passage of an electric current, the effect of which is to change the metallic lead of the Planté plate and the lower oxids of the Faure positive plate to the brown peroxid of lead, while at the same time the surface of the negative plate is reduced to spongy metallic lead.

During the discharge of the electric current the reverse takes place, and a certain amount of lead sulphate is also formed, so that an old storage battery plate is covered with a mixture of lead sulphate and oxids. There are many processes, therefore, in the making and repairing of these batteries which are attended with the formation of lead fumes or metallic lead dust or lead oxid dust and in which the workman's hands and clothes become covered with these substances.

First, there is the casting or molding of the grid or plate from molten lead which usually has a small percentage of antimony added, and this antimony may carry arsenic as an impurity. In American factories the kettles containing the molten lead are usually hooded, but this protection is not always provided and it is very common to see even in good factories the fumes from the kettles escaping freely into the air. It is customary to prepare the molds for the molten lead by dusting them with finely ground soap-stone or by passing a jet of smoky acetylene gas over the molds till a layer of carbon has formed. These procedures make the room very dusty, but are quite harmless.

Casting.—For Planté cells the grid is cast in ridges and furrows, or it may have roughened markings on the surface or spaces filled with rosettes of lead ribbon. Faure grids are made in such shape as to hold large quantities of lead oxid paste. For convenience in handling, grids are often cast in pairs and then sawn apart by a machine. The edge of the grid must be smooth and the superfluous lead cut or filed away either by hand or by machine. There is a handle on the grid, called the "lug," which projects from the battery and forms part of the connecting system, the lead connectors being

fastened on here. The lug is cast in one piece with the grid, if it is small, but large grids must have the lug burned on to the body. This burning is done in the casting room. Planté plates are cut in furrows by machinery in this same room, but there is no dust because water or oil is used to keep down the heat.

Pasting.—Up to this point, if processes are properly separated, the workman has been exposed only to lead dust and possibly to fumes from the kettles, except that in plants that use gas for heating there may be appreciable quantities of carbon monoxid in the air. From this point on a new danger enters, the paste which is made of oxids of lead. Mixing the dry oxids for the paste is very dangerous work unless it is done mechanically in a tightly closed apparatus. The worst method is fortunately used only in smaller plants, each mixer making his own paste on his own bench. In this way all the men come in contact with the dry oxid. Pasting the plates; that is, rubbing and pressing the paste into the interstices of the grids for Faure cells, is regarded everywhere as dangerous work, and various devices, some of them elaborate, expensive and quite useless, have been installed in the effort to protect the workmen. The important thing to remember is that the danger comes from dust and from the possible contamination of food with lead-covered hands. Therefore the question of protection can be solved only by prevention of dust and by provision of ample washing facilities. Elaborate exhausts at work benches are absolutely useless. The best plant I have seen has built the pasting room with a cement floor sloped to drains. This is flushed repeatedly during the day, the pasters standing on small elevated platforms which are also washed from time to time. A raised rim around the edge of the bench keeps the paste from dropping on the floor and the benches are washed at the end of the day's work. The men are provided with working clothes and there is a complete lavatory with shower baths. It is doubtful whether gloves afford much protection for pasters since the men are so likely to take them off and then put them on again over dirty hands.

Machine pasting is carried on at present in only one American plant. It would seem to be a great advantage, not only in lessening the number of men exposed, but in lessening the exposure. As a matter of fact only the first advantage is attained in this factory; for the pasting room is so impregnated with oxid dust, and the whole process is carried on so recklessly that the men are more exposed to dust than they are in the better hand-pasting factories.

One kind of Faure plate is known as the "Ironclad." This is a light grid made of slender vertical rods of metal over each of which is slipped a very loosely fitting rubber tube with slits in its circumference. The grid is placed upright on a table under a glass case and dry red lead is forced into the spaces between the rubber tubes

and the rods, the grid being violently shaken all the time to pack down the red lead. I have never seen this work so managed that there was not an excessive amount of red lead escaping from the apparatus.

Forming.—The pasted plates except the very small ones, are dried till the surface has set like cement and are then carried to the forming or pickling room, usually large and well-ventilated, filled with long troughs of dilute sulphuric acid in which are immersed the plates connected by a copper bar. A current of electricity is sent through the plates and when they are taken out they have been “formed” and the positive one is covered with a coating of the brown peroxid, the negative, with gray spongy lead. In this room, and to a slighter extent in the charging room where a second similar treatment takes place, the fumes of sulphuric acid are strong enough to cause much discomfort to a person who is not accustomed to them, but the men working there do not suffer from any irritating effect upon the eyes and throat, and German factory inspectors say that physicians find no abnormal amount of lung trouble or inflammation of the eyes among these men. Bottrich (1), one of the physicians of the great Hagen factory, believes that these acid fumes are actually beneficial; but Chyzer (2) of Bohemia takes a quite contrary position. He says that the bubbles which are always rising from the acid troughs carry with them tiny drops of acid and in one forming room with open windows he found a deposit of 1.28 grams of sulphuric acid on one square meter of surface; in another, with closed windows, 3.97 grams. He believes that workmen often suffer from bronchitis and nose-bleed and that the acid eats away the enamel of the teeth. A rare but serious danger in the forming and charging department is mentioned by Rambousek (3); that is, the formation of hydrogen arsenid fumes if arsenic is present as an impurity in the acid or in the lead-antimonial alloy. (See page 227.)

Assembling.—In American factories I could find no evidence of any harmful effect on the health of the men from conditions in the forming room, and this department is certainly the most healthful in the industry. The formed plates are taken from the acid, dried, and carried to the assembling and lead burning room. Here the dusty processes begin again. A group of positive plates is fastened together by lead strips and then fitted with a group of negatives, and between each pair of plates is slipped a thin strip of wood. The groups are fastened together by lead burning, a soldering process, in which pure lead is used and heat is applied by an oxygen-air flame. Various other processes go on in this room which are productive of oxid dust, such as straightening, trimming and filing plates, and cleaning edges and lugs of pasted plates. This last work is in some factories more productive of plumbism than any

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other. It is possible to clean lugs on a machine with a good exhaust.

Finishing.—The assembled plates are then charged by the passage of a second electric current, and then the finishers place them in cells filled with acid, and fasten on the covers and the outer connectors, thus making up the batteries. The only lead work here is soldering the outside connectors and burning the lead lined containers for large batteries.

During 1914, I investigated the conditions in the largest plants in the country and collected all the available records of lead poisoning which had come under the care of physicians during the preceding year. At that time the sanitary conditions of these plants left much to be desired and the personal care of the men was very inadequate. A second investigation, made in the summer of 1918, showed very decided improvement in one plant, which may now be considered in an excellent condition, and showed two more fairly well managed; but on the whole it must be admitted that the making of storage batteries is still one of the dangerous lead trades in the United States. The records of cases which I secured in 1914 numbered 164. These had developed during 1913 in five plants employing about 915 men, which would make a rate of 17.9 per hundred employed. The 164 men were engaged in the following processes: casting Faure and Planté plates; trimming and filing; mixing oxids; making paste; pasting plates; cleaning pasted plates; taking papers off pasted plates; carrying pasted plates to the forming room; cleaning lugs; assembling; lead burning; filling ironclad plates with dry oxids.

Work of this sort is largely unskilled; the men make low wages; they are likely to quit as soon as they find that their health is suffering; and therefore the turnover is very great and the histories of cases of lead poisoning usually show a short period of exposure. Among 70 such cases it appeared that three had worked less than one month; 41, less than six months; and only 7, more than one year. An analysis of the distribution of cases in the different departments of two plants gave this result:

Occupation	Employees Exposed	Cases of Plumbism	Rate per 100 Employed
Casting Faure and Planté plates.....	177	3	1.7
Mixing dry oxids and filling ironclads	20	8	40.0
Pasting plates	160	31	19.4
Assembling and lead burning.....	262	28	10.7
	619	70	11.3

The cases are usually acute with colic, and in severe instances with encephalopathy. The symptoms of 40 cases were described in

detail and 24 had typical lead colic; 9, abdominal pain; 7, no abdominal symptoms. In 22, anemia was marked; in 27, there was constipation; in 3, diarrhea; vomiting in 7; persistent nausea in 4; severe headache in 9. Pains in the muscles and painful cramps were prominent symptoms in 7. Twenty-three out of the 40 had nervous symptoms. Five of these are noted as showing "marked nervousness"; 4 had "mental dullness"; 4 had obstinate insomnia; 4, weakness of the wrists; 3 had wrist palsy; one suffered loss of consciousness at the beginning of his attack of colic; another was taken with violent delirium while in the hospital for colic; and another had repeated attacks of epileptiform convulsions.

The only fatal case reported during 1913 was that of a Polish workman who had been employed for about two months, at what particular process is not known. According to the statement of the two physicians who saw him, he was taken with acute lead colic and his friends advised him to drink whiskey to stop the pain, which he did to such an extent that he developed acute alcoholism also, followed by delirium tremens and death. The death certificate gives lead poisoning, with acute alcoholism as contributory cause.

The history of the storage battery industry in Germany is interesting. Our rate of plumbism in 1913 was something over 17.9 per hundred employed. Twenty years before that, Germany had a rate of 14 per cent which was regarded as frightfully high ("erschreckend hoch"). The large factory at Hagen began then to introduce reforms, and in 1898 the following measures were made compulsory in all plants: all rooms in which lead is handled must have smooth, hard, impermeable floors, not of wood or of soft cement or of linoleum, and they must be cleaned with water twice a day; the walls must be smooth and twice a year must be covered with washable paint or whitewash; the different processes must be kept separate; exhausts must be installed to carry off fumes and dust from casting, lead burning, cutting, polishing, mixing; there must be a separate lunch room; washing rooms must be provided with soap, towels, and brushes; cleanliness, including a bath once a week, must be enforced; the employer must provide full suits of washable clothing and caps; no women or minors may be employed; pasters and mixers may work only eight hours, with one and one-half hours for lunch, or six consecutive hours; all must be examined by a physician once a month. In addition to these legal requirements the Hagen factory provides milk free of charge, and gives gloves to the men in the casting department. Dumping of oxids and mixing of paste is mechanical and enclosed. The positive plates are Planté, the negative, pasted by machine. The physician in charge makes blood examinations, and suspends or transfers all who show more than 200 stippled cells per million. This record shows clearly the effect of these reforms:

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Year	Rate per 100
1897.....	21.16
1898.....	7.55
1899.....	2.85
1900.....	2.01
1901.....	0.97

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CHAPTER 13

GLAZES AND ENAMELS. PORCELAIN ENAMELED SANITARY WARE. THE POTTERY TRADES

GLAZES AND ENAMELS

A GLAZE consists of silicates or borates or both with a base which may be baryta, aluminum, tin, zinc, or lead. Tin and zinc are added for opacity, lead oxid is added to increase fusibility. The more silica, the higher the fusing point; the more lead, the lower. Fritting is uniting the powdered materials by heat. If it is carried farther, vitrefication, which is necessary for very homogeneous glaze takes place, and in such glaze lead is not used. When lead is used, it may be added at the beginning and in this case the fritting causes it to be changed in part to the poorly soluble disilicate. This is done in British and in German glazes and the fritted glaze is much less poisonous than the non-fritted, but in American potteries the lead is often added after fritting is over and undergoes no change.

A soft glaze, almost always a lead glaze, is used on terra cotta which, since it is porous, cannot be heated much or it would lose its form. The lead for the glaze is fritted with the other ingredients and is sprayed on. The glaze sprayer cannot help inhaling fine droplets even when an exhaust is provided, and since the fritting does not render all the lead insoluble there is some danger of lead poisoning.

Enamels are mixtures of silicates, borates, fluorids, and the alkalis,—sodium, potassium (introduced as feldspar, nitrates or carbonates); alkaline earths, calcium magnesium, and barium; and the opaque enamels usually contain lead and always tin. The transparent enamels also may have lead. The advantage of lead is that a lead enamel is easily prepared, is fusible and brilliant, but it is softer and not so permanent as leadless enamels. Lead enamel on sinks and bath-tubs gradually deteriorates under the influence of hot water and soap.

Hard glaze and leadless enamel require a high temperature for fusion. Vitreous pottery is covered with leadless glaze, and so is vitrefied brick, and bricks used for sanitary purposes, and the great majority of roof tiles and all hollow tiles, drain tiles, fire bricks and very cheap earthenware.

Lusters, applied to very fine pottery, consist of a thin layer of

finely divided metal, such as gold, silver, copper, platinum, lead, or iron. The enamel for clock and watch faces may contain tin oxid for opacity, arsenic for clear glaze, and lead for fusibility.

The enamel used on cooking utensils in the United States is lead free. According to Professor A. V. Bleining, stoneware is not covered with a lead glaze since it is fired at a high temperature and does not require lead. The enamel used on metal signs may or may not contain lead, but most such enamels would probably be found to contain lead, and practically all of them have arsenic as an ingredient.

Porcelain Enameled Sanitary Ware.—The making of porcelain enameled sanitary ware or hollow-ware such as bath-tubs, sinks, basins, etc., is a more highly developed industry in the United States than in any other country. I investigated it in 1911 and at that time there were ten large or fairly large factories operating in the following cities: Chicago; Sheboygan, Wis.; Louisville, Ky.; Chattanooga, Tenn.; Salem, Ohio; Pittsburgh, Monaca, Zelenople, and New Brighton, Pa.; and Trenton, N. J. A little more than one thousand men were employed in preparing the enamel and in applying it to the iron ware.

At that time an analysis made of seven samples of enamel showed the following quantities of soluble lead; that is, the per cent of lead found in solution in a 0.25 per cent hydrochloric acid after two hours (Thorpe test).

Sample No. 1.....	0.51
“ “ 2.....	2.55
“ “ 3.....	6.31
“ “ 4.....	8.35
“ “ 5.....	9.04
“ “ 6.....	10.22
“ “ 7.....	20.4

Whether or not less lead is used at present in sanitary ware glaze I have been unable to discover.

Mixing the enamel is always done in rooms separate from the enameling and is usually carried on by men quite ignorant of the nature of the powders they are handling, and often very careless. The ingredients are fused in fritting ovens and the dry frit is ground and in the course of these processes, especially dumping and shoveling, a great deal of lead-laden dust is produced. There was great difficulty in getting any information with regard to lead poisoning among these men; for they were largely recruited from the newly arrived immigrants and the labor turnover was great. Out of 45 whom I questioned, only 16 had worked in the trade as long as one year. One American workman I visited during a severe attack of acute lead poisoning. He had been employed for only

four weeks in a mill room with a leaking mill and he had not known that the work was dangerous.

Enameling is usually carried on in large, well-built rooms, with brick or cement floors, high ceilings, ventilated both from the sides and from the roof, and sometimes with exhaust ventilation over the furnace. The bath-tubs, sinks, basins, etc., come from the sand-blasting department to the slushers, who paint them over with the slush or ground coat. This was said by various manufacturers to contain from 0.25 per cent litharge to 8 per cent red lead. If the room in which this is done is separate the slushers run no risk, but ordinarily they work at one end of the enameling room. The ware is then handed over to the enameler and his helper who put it into the furnace till it is red hot. It is swung out by machinery to a turn table in front of the furnace door, and the helper turns the ware while the enameler shakes the powdered glaze over it, using a dredge. The large dredges are so heavy that they are suspended from the ceiling by a chain. They are worked by compressed air or by electricity, a rod inside driving back and forth and shaking out the powder. The men say that the shock of the driving rod in the larger dredges makes the work very tiring.

The heating and enameling must be repeated several times, the ware being returned to the furnace after each coat and then brought out for another coat. Large ware must remain several minutes in the furnace and in this interval the men can go over to the windows to cool off or to sit down and rest. Small ware does not take so much enamel nor so much strength to handle, but the work is more nearly continuous, because the pieces heat so quickly. In putting on the first coat, the enameler can stand at a distance from the ware, about four feet from the small ware and seven or eight feet from the large, but the last coat must be put on with great care so that no uneven places shall be left, and for this the man must come as close as the heat will permit. He sometimes uses a wooden mask with eye holes and a projecting handle, which he places between his teeth. Sometimes the very last coat of enamel is dusted on by hand.

This is above all things a dusty trade, and for at least two-thirds of the working day the enameler and his helper are breathing finely ground glass with soluble lead. It is impossible to realize how dusty the work is without seeing it. In every place I visited, walls, ceiling and windows were white with dust and in spite of ventilators, hoods, and open windows the air is always cloudy with dust when work is going on. The enamel powder, consisting as it does of ground glass, is not light and an upward draft carries off only a small part, while side drafts simply blow it about. The one thing that places a limit upon the accumulation of dust in an enameling room is the fear that it may blow down or be shaken down from ceilings or beams and spoil the hot ware. Cleaning is usually done in the worst possible

way, by blowing the dust out with compressed air and then sweeping it up from the floor. One manager has the men use a hose to flood the whole room, walls and ceilings, and he told me that there was no reason why this should not be done everywhere.

The men who handle small ware do not have to make much physical effort to get their ware in and out of the furnaces, but handling the bath-tubs requires all their strength, even with the aid of the mechanical appliances. The great heat from the furnaces is exhausting, especially in summer, and especially to the men enameling large ware. At that time (1911), the hours in summer were shortened and four shifts employed instead of three in some factories, but in others the long shift came during the summer and the short shift was introduced when work was slack.

It was very difficult to discover the cases of lead poisoning which had developed among the men in this trade, especially in such cities as Chicago and Pittsburgh, where the factories draw from the Slavic quarters and one must deal with many non-English speaking men whose real names are often unknown to their employers. Partly from physicians and hospital records and partly from personal examination of the men, I secured reports of 217 cases of lead poisoning which had occurred in 1911 among 1012 men, most of them coming from the 900 enamelers. One hundred and ninety-nine of these men were still employed at the time, which should mean a rate of almost twenty per cent of the working force. However, I was convinced that the rate was really much higher. It so happened that men were out on strike from two plants at the time of this inquiry and I was able to examine 148 of them. Since it was impossible to make examinations of blood and urine, I adopted the following standard for diagnosis: a lead line on the gums, unless there was an extreme condition of inflammation, with pyorrhea and loss of teeth; pallor of skin and mucous membrane, often extreme sallowness; marked loss of appetite and distaste for food, for breakfast, especially; increasing loss of strength; gastric disturbances of various kinds; history of ill-health dating from their present occupation. Thirty-five men with a clear lead line gave this symptom-complex, and in addition 16 of them complained of obstinate constipation; 13, of persistent headache; 11 had lost weight; 10 complained of nausea and vomiting; 5, of pains in the joints; 2, of tremors; one, of dizziness. Another group of six men with the same character of symptoms showed only a slight lead line or none, but an extreme condition of inflammation of the gums. These six men had worked a longer period than the average, ten and a half years, while the whole group of 148 averaged less than six years. Thirteen others had a history of colic, severe enough to require medical treatment, and I was able to obtain confirmation of the diagnosis of lead colic from the physicians who had treated them.

At the time I examined them they were suffering from indigestion, the lead line was apparent in ten, pyorrhea in three. In the case of 38 more men I felt that a more thorough examination—blood and urine—might have revealed plumbism, especially in 15 who had very suggestive symptoms, but no lead line. Twenty-three of the 148 strikers were in good health, but had a clear lead line. This left only 56 out of 148 with no suspicion of lead absorption. To sum up, among these 148 enamelers, 54, or 36 per cent, showed evidence of chronic plumbism; 56, or 37 per cent, did not show any evidence of plumbism; 38, or 25 per cent, were not free from suspicion, but could not be regarded as clear cases.

The character of the disease in this trade is often very serious. This is the record for the four plants in the Pittsburgh region for two years, 1910 to 1912: 385 men on the payroll; 165 cases of plumbism, including 11 deaths, 25 cases of palsy, and eight of encephalopathy.

If we should divide into separate classes according to severity the 182 cases whose history was given in detail, following the method used by the British in their reports, the result would be: 40.6 per cent slight cases, 42.0 per cent moderate, 14.0 per cent severe, 2.7 per cent fatal. It is probable, however, that such a classification of American cases would be inaccurate, because in this country we must depend to a great extent in collecting histories on the memory of the practicing physician, and he is more likely to remember the severe cases than the slight.

Eighty-two out of 186 lead poisoned enamelers had had more than one attack. The length of exposure before the first attack was less than six months in 25 men; less than a year in 45; and from one to ten years, in 45.

THE POTTERY TRADES

The principal centers for the making of white ware, which means sanitary earthenware and table and toilet ware, are Trenton, N. J., and East Liverpool, Ohio. This branch of the industry is well organized and the U. S. Potters' Association, an organization of manufacturers, makes regular working agreements with the National Brotherhood of Operative Potters, as a result of which arrangement the industry has been free from strikes for a long period. Yellow ware and Rockingham, decorated bowls, jardinières, pedestals, spittoons, etc., are usually classed together as art and utility ware, and the chief center for this manufacture is Zanesville, Ohio, although utility ware is still made in East Liverpool. Glazed tiles are made in the Trenton district, the Zanesville district, the Cincinnati district, Indianapolis, and Chicago.

A recent report on lead poisoning in the pottery trades published by the U. S. Public Health Service covers 92 plants, in New Jersey,

Pennsylvania, Ohio, and West Virginia.* The Ohio pottery field is much the most important and the West Virginia field is closely bound to it. Of the 26,705 persons employed in 1914, 11,096 were in Ohio. Ten years before the publication of this report I made an investigation of the same field with the exception of Pennsylvania and my findings were published by the U. S. Bureau of Labor. This later investigation by the Public Health Service is far more extensive and complete than mine and I have drawn largely from it in preparing this chapter, but apparently there has been very little change in the sanitary conditions of the potteries in the ten years intervening between the two studies and the dangerous features which impressed me in 1911 are described by the Public Health Service investigators as still present in 1921.

The processes which involve the risk of lead poisoning are: mixing the glaze; dipping the ware in glaze, or pouring glaze over it, or painting it with glaze; handling the ware while the glaze is still wet; removing excess glaze from dry ware; decorating the ware by color spraying or color dusting; and cleaning or sweeping dusty floors, boards and benches.

The degree of danger involved in these various processes depends partly on the amount of lead used in the glazes. In the white ware potteries I visited, the glazes contained from 1.75 to 33.3 per cent of white lead. In the art and utility ware potteries and the tile factories the glazes contained from 5 to 60 per cent of white lead, rarely red lead. The glaze with the smallest percentage of lead is that used for large sanitary ware; indeed earthenware bathtubs may be covered with a glaze free from lead. The largest percentage of lead is used in the glaze for colored tiles, for yellow ware and Rockingham, and for certain kinds of art pottery and majolica, because such ware is fired at a low heat to prevent alteration of the colors and lead makes glaze more easily fusible. Table and toilet ware occupy a middle place. Small sanitary ware has less lead in the glaze than table ware.

English literature on lead poisoning in the potteries contains many references to "fritted glaze," which means that the lead has been added to the mixture of raw borates and silicates and the whole fused till it is a liquid mass. It is then run into water where it scatters and hardens quickly in feathery masses, known as the "frit." This is then ground to powder and whatever lead has been added has been largely changed to the harmless lead disilicate. In American potteries the lead is usually added after fritting, and therefore its solubility is not in the least diminished. A great deal of leadless

* *Lead Poisoning in the Pottery Trades*, B. J. Newman, W. J. McConnell, O. M. Spencer, and F. M. Phillips. U. S. Public Health Service Bulletin No. 116, May, 1921. For a summary of their findings see "Book Review," *Journal of Indust. Hyg.*, 1922, 3, 390.

glaze is used in England, but the Public Health physicians found no leadless glaze in use in American potteries. Most of the glazes were rich in soluble lead, that is, lead which passes into solution in a fluid containing as much hydrochloric acid as does human gastric juice. Of 107 samples which were analyzed, 73 per cent contained over 10 per cent soluble lead, and eleven had from 20 to 50 per cent.

The dangers in the mixing room come from shoveling, weighing, and carrying the white or red lead that goes into the glaze and from grinding and sifting the glaze. This work is done by men who do not belong to the trade union, are quite unskilled, do not know one powder from another, and are unaware that there is any risk involved in their work. The Public Health physicians found a higher dust content in the air of the mixing rooms than in any other department. The liquid glaze is applied to table and toilet ware by dippers who are highly skilled English-speaking men. The process is the same in art potteries and utility ware, but, these branches being unorganized, the dipper may have other work to do as well. Some dippers also do the finishing, either sponging the ware or scraping the glaze off after it has partly dried; others spend part of their time laying on colors or colored glazes with a paint brush.

In the organized field the dippers' helpers work beside the dipper, they sponge or clean the ware to get rid of the glaze on the foot, stack the ware on boards or trays and carry it to the glost-kiln for firing. Sanitary ware is large and heavy and the helpers in these potteries must be well grown boys or men. In "general ware" potteries (table and toilet ware) where the pieces are smaller, the helpers are girls, women, or boys. In the Trenton district, the helpers, boys or men, simply stack the ware on boards and carry it to the kiln where it is finished (the excess glaze rubbed off), by the kilnmen, who rub off the dry glaze on an apron or band of cotton duck tied around the waist. In the East Liverpool potteries the helpers are all women and girls, who have to clean the ware usually with a sponge, sometimes with a piece of rough carpet, and gather up the dry glazed ware and pile it on boards for the kilnmen to carry off.

The dipping or glaze room is almost always full of glaze dust. The floor often is of wood, rough and worn out, and deeply impregnated with dried glaze, and there are accumulations of glaze dust on ware boards and racks. Handling these boards, dropping them frequently down on end, and sweeping the floor, all keep the dust stirred. The Public Health physicians found more soluble lead in the air of the dipping rooms than anywhere else, 55 out of 90 specimens of dust having from 10 to 50 per cent of soluble lead.

Glazing tiles is done in one of three ways: by hand dipping, pouring, and machine dipping. In hand dipping, the tile need not

be plunged in the glaze; for only one side is glazed, and so the dipper's hands are not covered with glaze, as in pottery dipping. In pouring the glaze on small tiles a number of them are placed on a sloping drain board beside the glaze tub; larger tiles, such as roof tiles, are held one by one over the dipping tub while the glaze is poured and the man can keep his hand quite clean if he is careful. The method most often used, especially for wall tiles, is machine dipping and no hand work is required except to place the tiles on the traveling belt of the dipping machine and to take them off after they have passed over the glaze. There is no splashing from such machines and no excess glaze must be scraped off, which makes the work much safer.

Finishing tiles as carried on in American potteries is very dangerous work. The glaze that runs down over the sides must be scraped off with a dull knife or sometimes brushed off. If this is done before the glaze is quite dry, as is the rule in England, and the glaze is allowed to fall into a trough of water there need be no dust, but in our potteries tiles are often kept over night or even over Sunday before they are finished and the girl and boy "fettlers," as they are called, scrape and blow away a fine powdery glaze, containing sometimes as much as 60 per cent of white lead, and the white powder can be seen on their clothes and hair and even in their nostrils.

Two very bad methods of glazing tiles consist of applying dry colored glaze over the liquid glaze and of sprinkling a second glaze over the first to make onyx tiles. This second glaze may be dabbed on with balls of cotton soaked in glaze or scattered from a pail by hand.

The glost-kilnmen place the glazed ware in glazed earthenware boxes called "saggers." There is always some glaze dust in the kiln room but it is especially abundant in the Trenton district because there the kilnmen finish, that is, rub the excess glaze from the ware as they do not in other districts. Decoration is not attended with nearly so much danger as formerly because the demand at present is for clearly defined patterns on a white ground, and this is accomplished by the use of decalcomania papers, perfectly harmless work. Hand painting, even with lead colors, is also harmless; for the paints are in an oily medium and are applied with a brush. The grinding and sifting of lead colors and the work of tinting and ground-laying are all attended with decided danger, but there is much less of this work done all the time. Tinting is the process spoken of in British reports as "color blowing." The ware is held under a hood with a fan to draw the air away from the operator who sprays the color through an atomizer with compressed air. In spite of the draft in the hood some of the spray always blows back over the tinter because the suction cannot reach those droplets which are driven

against the side of the ware. I found eight cases of lead poisoning that had occurred among decorators in two years' time, five in women and three in men. It is in the art potteries, especially, that color tinting is done. Ground-laying is done occasionally, only when a solid band of color is required. It consists in dusting dry colors on a prepared surface by means of pads of cotton.

The sanitary conditions in this industry were very poor in 1911, especially in the glazing and decorating of art and utility ware and of colored tiles, and unfortunately these are the potteries which use glazes with the highest proportions of lead. The report of the Public Health Service shows practically no improvement since 1911. The floors are still of wood and are often swept dry. In 25 of 92 potteries this dry sweeping went on during working hours. In not one plant did the investigators find a separate modern washroom provided for the use of the employees; "in many of the plants the workers washed either in basins removed from the racks or in troughs used for washing the ware and ware boards; in quite a number of plants the dippers and dippers' helpers are known to wash their faces and arms with the sponges which are used to clean the sides and edges of the dipping tubs." Other details are of the same character: clothes hang in the dipping room; drinking cups and uncovered pitchers of coffee or water stand in the dipping rooms, often with a scum of dust visible on the surface, and lunch is eaten in the dipping rooms. There is no medical supervision, no examination of the workers, no effort to diagnose lead poisoning in its early stages, and no effort to instruct the workers in the proper ways of preventing lead poisoning.

It may be illuminating to insert here a description of the potteries of Staffordshire which I visited in the summer of 1912. These were the Doulton and the Grindley potteries in Burslem, the Star China Company and the Royal Art Pottery in Langton, and the tile factories of Malkin in Burslem, and Minton and Hollins in Stoke-upon-Trent. This industry in Great Britain is governed by special rules which are modified according as the factory uses a glaze rich in lead or the reverse. Every inducement is given to the manufacturer to reduce the amount of soluble lead in his glaze and thus escape the irksome rules in force when the glaze contains over five per cent. I selected for my visits potteries which were all under these rules. They are obliged to employ a physician approved by the Home Office to examine once a month all men and women exposed in any way to lead, and the cases of lead poisoning discovered by him must be reported to the Home Office. The employer provides, mends and launders full suits of washable working clothes, one clean suit a week. Men wear overalls and caps, women full high-necked and long-sleeved aprons of some light colored calico, and a washable cap. Toilet rooms must contain one basin with

hot and cold running water for every five employees, towels, soap and nail brushes. The workers who come in contact with lead are required to take off their working clothes and wash hands and face before leaving work or going into the lunch room, the only place where they are permitted to eat or to keep food. It is customary to allow fifteen minutes in the middle of the morning and afternoon for tea and an hour at noon.

In order not to bring under these special rules any more workers than is necessary, the lead processes in British potteries are strictly divided from the others. The dipping rooms must be constructed so as to allow perfect cleaning and they are kept clean. The floors of these rooms are of cement or brick or dark red tiles, sloping to a drain. White drops of glaze would show plainly on such a floor and splashing is not allowed; for it is wasteful as well as dangerous. The dipping rooms in Malkin's pottery have white tiled walls and the whole room can be flushed with a hose. The floors are never swept dry but are washed or flushed every evening. The boards on which the glazed ware is placed are beautifully clean; for they are washed every evening.

Finishing, if dry, is done over a large vessel or shallow sink of water, which catches all the heavier particles of glaze, and in front of an air exhaust which carries off the lighter particles. The dust is used to glaze the inside of saggars; the glaze caught in the water is used for ware again. The English consider it extremely wasteful to scatter this glaze about as is done in America.

Majolica painting and glazing and tile glazing and decorating in British potteries present a great contrast to the work as done in Zanesville and elsewhere in the United States; for the control of glaze dust seems to be almost perfect. For instance, at Minton and Hollins', colored tiles are dipped so skilfully by hand as to need no finishing. Cornices and other irregular shapes are painted with a brush and as soon as each is finished it is taken by a cleaner and scraped before the glaze has had time to dry.

In 1911 I tried to discover how much lead poisoning there was in the potteries I visited in New Jersey and Ohio. It was quite impossible to examine the men and women employed and all I could do was to secure from physicians and hospitals and from interviews with the workers, records of acute attacks of lead poisoning or chronic lead poisoning which had been diagnosed by a physician. My results were as follows: Among 1100 men, there were 87 cases of plumbism occurring in 1911, which would mean that one in every twelve to thirteen men suffered; among 400 women, there were 57 cases, or one in seven women. A single local of the Dippers' Union showed me its records for one year and out of 85 men, 13 had had acute lead poisoning during that year. The rate was distinctly higher for the men in the unorganized branches of the

trade than in the organized, although it was much more difficult to secure information in the former. Thus, for 1911, the rate for white-ware men was 4.75 per cent; for white-ware women, 19 per cent; for men in art and utility ware and tiles, 15.8 per cent, and for women, 14.8 per cent.

The women in the white-ware potteries suffer more in proportion to their number than do those in the other branch because all women in the glaze departments are doing dangerous work, while in the tile factories many women are engaged in the comparatively safe work of placing glazed tiles in receptacles to be fired. The difference between the two classes of men depended apparently partly on the high lead content of the glaze used on art and utility ware and tiles and partly on the low wages paid in the unorganized field; for the contrast between the living conditions in these two branches is very great indeed. The cases of encephalopathy found in this investigation were fourteen, and nine of them were in women.

The report of the Public Health Service is much more accurate, being founded on an examination of 1436 men and 373 women, 1809 potters in all. The authors are very cautious in making a diagnosis of lead poisoning and they group the cases under three heads: positive, presumptive, and suggestive, although they believe that these groups represent different degrees of plumbism and the first two may, for all practical purposes, be considered together. If the third group, containing suggestive cases, were divided evenly between positive and negative, the rate would be 22.8 per cent for all examined, with a rate of 23.1 per cent for men and 21.5 per cent for women. This last estimate seems sufficiently conservative, in view of the description of these so-called suggestive cases. They are workers exposed to lead who exhibit some combination of the following symptoms: constipation, loss of weight, loss of strength, drowsiness, pain in the lumbar region, pain in joints, headache, sleeplessness, loss of morning appetite, metallic or sweetish taste.

In contrast to this is the British record. The last full report of the British Factory Inspection Department concerning plumbism in the potteries is for 1913. In this year there were found 62 cases of plumbism among 7085 employed, making a rate of 0.9 per cent, with 0.1 for the women and 0.8 for the men. The dippers had the highest rate, 2.4 per cent. It seems probable that even this excellent record has been improved in recent years; for there were only 21 cases reported for 1919, but the number of persons exposed is not given in that report.

The low rate of plumbism for women shown in the Public Health Service report as compared with men is only apparent and a closer study showed that women are actually more susceptible. Comparing the men and women who work side by side in the dipping rooms it was found that there were no cases at all among 58 male ware-

carriers, while among 62 women there was a rate of 4.8 per cent. Among 71 male dippers' helpers the rate was 8.4 per cent, but among 149 female helpers it was 14.4 per cent.

The same report contains striking figures as to the dust content of the air in different departments and the amount of lead in the dust, and also as to the increased incidence of plumbism in factories where ordinary hygiene is grossly neglected, and as to the increase in plumbism when the working day is lengthened. The statement is made that this is an industry which has been growing in importance of late years in the United States and that of the 92 potteries visited, 62 employed from 100 to 250 persons and 19 employed 500 or more.

CHAPTER 14

THE PAINTERS' TRADE

It is impossible in the United States to discover even approximately the proportion of painters who suffer injury from the use of lead paint; for we do not even know how many painters there are in the country or how many of these are exposed to the danger of lead. It is, of course, the most widespread of the lead using trades, even more general in its distribution than printing or plumbing; for it is safe to say that there is no community so small as not to give employment to at least one painter.

The industry falls naturally into two classes: first, the independent house and sign painters, working now for one contractor, now for another, and using paints of widely differing composition and applying them in different ways according to the ideas of the contractor under whom they work and the cheapness or expensiveness of the work. Their employment is largely seasonal and they have long periods of unemployment, but to offset in part this disadvantage they are, in most cities at least, members of a strong labor organization with power to influence in great measure their hours of work and the conditions under which the work is done. House painting is a skilled trade requiring an apprenticeship of three years, and sign painting one of four years, and these men are usually much above the average of wage earners in intelligence and education. Between this and the next class come the ship painters, whose work resembles house painting very closely yet differs from it enough to make a separate description necessary. The other large class comprises painters who work in manufacturing plants, factories or workshops of any kind. This class has much steadier employment, both as regards time and as regards character of work, than the house painters. They use the same kinds of paints and the same methods day after day, working with the brush, or dipping objects to be painted in large tanks of paint by the aid of machinery, or spraying paint by means of compressed air atomizers. Much of the work can be done by unskilled or semi-skilled men, and even newly arrived immigrants with no experience in anything but farm work are employed in this sort of painting.

This class of painters is not organized, yet union painters may take employment in open shops such as railway-coach and wagon and automobile factories, and it is not uncommon to find skilled

union painters employed at the better paid, more difficult parts of the work while unskilled, non-union men are employed at the simpler parts. No house painter can work for any length of time without being obliged to employ lead paint to some extent, but in factory work a painter may use leadless paints entirely. It follows that some classes of factory work are safer than house painting can be, but it is also probably true that some of the most dangerous work in the painters' trade is to be found in factories.

Paint is a mixture of pigment and liquid, either of which may be harmless or poisonous. High priced paints usually consist of white lead, linseed oil, and turpentine, the first and last of which are poisons. Cheap paints may contain as pigments nothing more dangerous than chalk or barytes, but the liquid portion may contain a large quantity of petroleum naphtha or coal-tar benzene or various so-called turpentine substitutes. Usually the cheaper the paint the more harmful the liquid portion, the dearer the paint the less harmful, with the exception of white lead paint used for high class interior work, which may be rich in turpentine. Gloss paint has varnish added and a relatively large proportion of oil; flat paint has less oil and either turpentine or benzin or benzene. In cheap gloss paints, also, the oil may be supplemented by melted rosin and benzin or benzene.

Liquid Constituents of Paint.—It has long been believed that surfaces freshly painted with white lead in linseed oil give off fumes or emanations which may cause more or less distressing symptoms in the painters and still more in the inhabitants of freshly painted rooms who are not accustomed to these fumes. Among the symptoms described are headache, dizziness, nausea, intestinal pain, vomiting, diarrhea. Such cases have been reported as caused by lead poisoning, and physicians have insisted that their occurrence proved the presence of lead in the emanations from fresh lead and oil paint. Oliver (1) speaks of an outbreak of colic among the sailors on a French man-of-war which was traced to the fumes from fresh lead paint.

In the Pasteur Institute in Paris experiments were made under the direction of Trillat which showed that fumes from white lead paint are capable of hindering the growth of vegetable molds. This was not found to be true of zinc oxid paint or of dry white lead or of turpentine. The harmful fumes arose from white lead paint only and were the result of the mixture of oil and white lead.

Similarly, E. C. Baly (2), F.R.S., finds that certain emanations which may give rise to the symptoms described above are given off from surfaces painted with white lead and oil, but not from white lead alone, or from oil or turpentine alone. However, Baly insists that the fumes in question do not contain demonstrable lead in any form, but consist of a gaseous product which produces symptoms

like those described as "due to lead poisoning." Baly concluded that the body was an unsaturated compound of great reducing power, in all probability an aldehyde. The histories of persons suffering from emanations from fresh lead paint are certainly more suggestive of a volatile poison than of lead which is much slower in its action.

Herman (3) of Belgium has for several years past carried on experiments which lead him to believe that fresh lead paint actually emits lead vapors or particles for about 48 hours after it has been applied, and he therefore attributes the poisoning of painters to these air-borne particles of lead. He claims to have found lead on a disc of filter paper placed in a drier above a layer of fresh white lead paint, and in 17 out of 20 experiments he succeeded in proving the presence of lead on slips of paper suspended at various heights in a room freshly painted with white lead paint.

Yet Moore, Oldershaw, and Williams (4), who placed cats, because they are unusually susceptible to lead, in freshly painted enclosures and left them there six or seven days, repainting each day (but guarding them against contact with the paint), came to the opposite conclusion. They believe that there are no lead emanations from fresh white lead or basic sulphate paint.

Great prominence has been given lately to the part played by turpentine in the ill-health of painters. Oliver (5) and Goadby (6) have both stated, with reference to the proposed prohibition of white lead paint, their opinion that much of the harmful effect of such paint should be attributed to turpentine. This question will be discussed more in detail in the section on turpentine. The other solvents with which painters come in contact are petroleum-benzin and naphtha, coal-tar benzene, amyl acetate, acetone, methyl alcohol, and certain chlorin derivatives of the paraffin series. A full description of the action of these compounds will be found under their respective heads.

The solvents listed above are used in varnish and shellac; in gilding, silvering and bronzing fluids; and in paint and varnish removers as well as in quick-drying paints. Benzin is also used in what is called "hard oiling." When a wall is to be kalsomined the plaster must first be covered with some gummy material to prevent the kalsomine from soaking in, and for this a mixture of hard gum, oil and turpentine, thinned with benzin, is used. Practically all painters complain of the discomfort they experience from fumes in hard oiling. The so-called bituminous composition which is used for painting the water bottoms of ships and for bridges and railway tanks is a mixture of petroleum, resin, and asphalt. It must always be applied hot and it gives off thick fumes which are very irritating, sometimes exciting, sometimes stupefying. H. A. Gardner (7) says that bitumastic paint with low-boiling naphthas made the men very ill, dizzy, weak, suffering from headache and confu-

sion, when they were working in small closed compartments in a battleship, even though air was blown in. When high-boiling petroleum distillates were substituted there was no further complaint.

Commercial benzene is a mixture of hydrocarbons, containing about 40 per cent of pure C_6H_6 , which has powerful solvent properties and penetrates deeply. On account of this it is used in primers on hard woods but cannot be used in finishing coats of varnish or shellac because it would act as a paint remover. Benzene enters largely into the composition of paint removers and varnish removers and it is now coming into use extensively as a constituent of quick-drying paints.

Methyl alcohol is used in varnishes and shellacs and also in varnish removers, but it is gradually being displaced by denatured grain alcohol. Amyl acetate, called by the painters banana oil, is usually mixed with acetone and naphtha or benzene and used in varnish, in bronzing, silvering and gilding fluids, and in paint and varnish removers. Another volatile compound which, according to the Bureau of Standards, enters into the composition of some paints is carbon disulphid. Many turpentine substitutes are now on the market and their formulas are often secret. One of the newer is tetralin, a trade name for tetrahydronaphthalene, which, according to German experience, causes, when used in a poorly ventilated space, irritation of the throat, headache, confusion, and a dark green coloration of the urine.

Pigments.—The important question with regard to the pigment in paint is whether or not it consists of a lead compound; for, with the exception of the anti-corrosion paints used on the hulls of ships to keep off barnacles, there is no harmful pigment except lead now used in paint. There are four lead compounds used as paints, of which the most important is white lead, the basic carbonate, often called Old Dutch Process or Carter Process white lead; next comes sublimed white lead or the basic sulphate; then, the oxids, red lead and orange mineral; last, chrome yellow or lead chromate, which, when mixed with Prussian blue, makes Brunswick or Prussian or chrome green. Of these, the first two are used for painting wood in exterior and interior construction. Red lead has long been considered the best paint for metal on account of its elasticity and its rust-preventing properties, but its expense has led to the use of cheaper substitutes, such as carbon paint, iron oxids, chromatized paints and coal-tar paints, for covering such metallic surfaces as structural iron, bridges, water tanks, gas tanks. Red lead is, however, still used on certain parts of the structural iron of bridges and railway cars and is largely used in the painting of steel ships, especially battleships. Orange mineral is used in wagon painting.

Chrome yellow is not much in demand now; for anilin colors and ochres are cheaper. It is still used for tinting in house painting

and on farm wagons and on the coaches of the Northwestern railway. Chrome green is still the favorite color for window shutters and shades.*

The putty used by painters may also contain lead. I have analyses of seven sash putties which were made for the Workers' Health Bureau of New York City, all but one of which show lead in quantity from 5 per cent to 20 per cent.

Methods of Applying Paint.—The dangers involved in the use of paint depend not only on the constituents of the paint but also on the way it is used. It is not true, however, that no paint need be dangerous if it be used with sufficient caution; for if the thinner contain volatile substances which are very poisonous, such as benzene, and the paint be used in interior decoration, it may be impossible to provide ventilation sufficient to remove the danger, especially if the spraying method be used. The avoidance of danger from the use of lead pigments is a simpler problem. In discussing the solid constituents of paint, foreign authorities give the following processes as involving danger to the painter: mixing dry lead salts with oil or paint; dry rubbing down of lead painted surfaces; rubbing or chipping old lead paint; burning off old paint; inhaling dust from dirty working clothes and from dirty drop cloths; carrying lead paint into the mouth from unwashed hands while eating or while handling tobacco.

The first of these dangers is fairly negligible in this country; for the painter almost never handles dry white lead and rarely, red lead. Out of 100 lead poisoned painters whose histories I obtained only two spoke of having used dry white or red lead. The second danger, however, is still an important source of lead poisoning. Sandpaper or sometimes steel wool is used to smooth away the roughness of one coat of paint before the next is applied. A well painted interior usually has from two to four coats of white lead paint, all but the last of which may be sandpapered. In a small enclosure, such as the lavatory of a Pullman car or the cabins and narrow corridors of a passenger ship, the air during sandpapering is filled with fine paint dust. Especially dangerous is sandpapering the ceilings; for the dust falls down in front of the man's face.

In working on wagon or automobile wheels the spokes and the hub of the wheel receive many coats and are sandpapered in preparation for these coats. The painter may spend from a sixth to a fourth of his time in this work which produces lead dust, and, of course, if he is working in a room with other men he is obliged to breathe the dust produced by their work also. The bodies of Ford automobiles are also sanded and the sanders are, according to Dean (8) subject to acute plumbism to a marked degree. Thus, among

* For the comparative toxicity of these different lead compounds, see Chapter 9.

71 cases of lead poisoning which Dean found in three Detroit hospitals, there were 38 sanders, one-half of whom had sickened within nine weeks of their employment on automobile bodies. This feature of the painters' work has attracted a great deal of attention in European countries and has been the subject of legislation in most of them. Rubbing with pumice stone and water is used abroad much more than it is in this country, but it is slower, and for the first coats it cannot be used because it would raise the grain of the wood or, in metal painting, might cause rust. If, therefore, sandpapering must be used it is customary, at least in Germany and in Scandinavian countries, to dip the sandpaper in some heavy mineral oil in order to prevent the dust. American painters do not consider this satisfactory, and experiments are now being made with a water-proof sandpaper which can be moistened with water. As the painters' work is increasingly speeded up, especially in house painting, less sandpapering is done and it is, therefore, not so important a feature of interior decoration in this country as it used to be.*

Old paint is sometimes prepared for repainting by sandpapering, when the surface is wood and when the repair is only superficial. Painted metal surfaces are usually chipped off with a compressed air hammer, and the danger of the work varies according to the lead in the paint and the smallness of the enclosure in which the work is done. The worst job of this sort is in repairing steel ships when the painters may have to enter the small closed spaces between the outer and inner shell of the ship and chip off old red lead paint. Stitt (9) reported three cases of encephalopathy in men doing this work on a torpedo boat in the Philippines and a large number of cases developed in the Brooklyn Navy Yard some years ago.

Burning off old paint is regarded as a source of lead poisoning by English and German authorities, but it seems improbable that lead fumes could be produced by the momentary contact between the small gasoline flame and the painted surface, as occurs in most work of this sort. Legge (10) warns of the danger of lead fumes when the oxyacetylene torch is used on painted steel in breaking up old battleships, for this steel has several layers of red lead paint. As much as 49 mg. of lead has been found in 10 cubic meters of air during such work, while an oxygen and gas flame volatilizes much less lead, producing an atmosphere with only 3.4 mg. in 10 cm.

* For a full discussion of the possibility of substituting zinc white paint for lead white see the Report of the British Departmental Committee on the Danger in the Use of Lead in the Painting of Buildings, 1914, reprinted by the U. S. Bureau of Labor Statistics, Bulletin 188, 1916. A good summary of the laws regulating this trade in the United States, Great Britain and Continental countries is contained in a publication of the Provincial Board of Health of Ontario, entitled *Lead Poisoning, a Compilation of Present Knowledge*, by R. M. Hutton, Toronto, 1923.

When sandpapering is done the paint dust falls on the floor or on the drop cloth. The floor of the factory is oily and the dust becomes incorporated in a paste, but when the floor is covered with a drop cloth, as in house painting, there is risk of contaminating the air with lead dust stirred up by the men as they pass to and fro, and there is even more risk at the beginning of work when a dirty drop cloth is first spread out on the floor and the accumulation of dust from sandpapering is shaken into the air. Dusty overalls are objectionable for the same reason.

It is impossible to say how much of the lead poisoning of painters is caused by the lead paint which is so often smeared over their hands. We have become accustomed to assume that skin absorption is practically negligible as a mode of industrial poisoning, but that belief rests on an assumption: it has never been proved.* The painter himself believes that lead enters the body in this way and that washing his hands in benzin or naphtha or turpentine favors the absorption, and it may be that his observations based on experience will prove to be right. Most authorities hold that the only way in which paint on the hands can harm the painter is by contaminating his food or tobacco, if he eats his lunch or handles his chewing tobacco with unwashed hands. The risk is greatest with greasy food, such as buttered bread and meat, for paint comes off easily on an oily surface. House painters have most difficulty in guarding against this danger; for the water is not usually turned on in a new building till the painting is over, and cold water in a pail without soap and towels is of little use. The thirty or forty minutes allowed at noon is seldom long enough to allow the house painter to eat his meal with clean hands in a clean place. In factories, the situation is much simpler and there is no valid excuse for failing to provide proper washing facilities and lunch rooms for the painters. Sign painting is safer than house painting because much of it is done out of doors, and even if it is done indoors there is little if any sandpapering and much less paint is used than by house painters: for a good deal of the sign painters' time is devoted to painstaking lettering and ornamentation. Moreover, the paint is not applied by spraying nor is it necessary to use a large proportion of volatile compounds.

There are two changes which have come fairly recently in the painters' trade, both of which have spread with great rapidity and both of which result in adding decidedly to the dangers of the industry. These are the use of quick-drying paints for interior decoration † and the use of the so-called spray gun for applying paint. The spray method of painting and varnishing has increased in popularity with bewildering rapidity during the last few years. The danger is

* See page 40.

† See Chapters 28 and 33.

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obvious. A finely divided spray of lead paint or of paint which is lead-free but contains volatile thinners of the petroleum or coal-tar series, is a very difficult thing to handle without poisoning the air which the sprayer must breathe. Agricultural machinery, automobile bodies and furniture are now usually painted by spraying, and although an effort is made to safeguard the painter by the provision of cabinets with exhaust ventilation, the practical difficulties are great. A much greater problem is presented by the use of the spray gun in painting walls and ceilings and shelves and mantel-pieces inside buildings.

When the spray gun was first introduced the protection provided the men was poor, and in 1915 Albaugh of the Ohio State Health Department reported that there were at that time approximately 2500 spray guns in use in the State and that only about 25 per cent were furnished with proper devices for safeguarding the health of the operator. Albaugh describes a case of fatal poisoning from the volatile solvents in a varnish, probably benzin and turpentine, which was used in a spray gun by a lad of 18 years. The patient consulted a physician just six days before death, complaining of great weakness, attacks of nausea, loss of appetite, tingling of the extremities, and hemorrhagic spots over the body. He had lost about eighteen pounds in the past six months. His temperature was 97.2, pulse 69, weak and irregular, and the systolic blood pressure was only 85. Two days later he was obliged to go to bed with an exaggeration of all his symptoms, systolic pressure 75, temperature below 94 (the thermometer was not graded below this), pulse 90, very weak and irregular. The urine was cloudy, acid, with traces of albumin, many hyaline and a few, finely granular casts, the specific gravity 1022. The red cell count was 3,500,000, the white count 12,400, the differential count normal. His condition grew steadily worse and on the fifth day he passed into a delirium and died on the sixth day. Three fellow workmen had suffered from similar symptoms in milder form.

In this connection it may be well to give some analysis of the newer paints which have been put on the market for use either with brush or spray:

	Pigments	Liquid Vehicle
Flat coat	Lead, zinc	Oil, benzene, traces of turpentine
Flat coat	Lead, zinc	Oil, benzene
Flat coat	Lead, zinc	Oil, benzene
Primer	Zinc	Benzene
Primer	Zinc, lead	Oil, turpentine, benzene
Primer	Zinc, lead	Petroleum ether
Primer	Zinc, lead	Turpentine substitute 50 per cent
		Petroleum substitute 10 per cent

	Pigments	Liquid Vehicle
Mahogany stain		Aniline, turpentine, benzene
Enamel		Turpentine, kerosene
Bronzing liquid		China wood oil, benzene
"Non-poisonous paint" Lead, zinc		Linseed oil, turpentine

In April, 1922, N. C. Sharpe (11) of Toronto University published a report of a very careful investigation of the hazards involved in using lead paint by the spraying method. He made up a paint with white lead for pigment, turpentine, linseed oil and benzin for the liquid vehicle, and this he used in a spray with a pressure of 35 to 55 pounds per square inch. Specimens of air were collected by Duckering's method, the samples being taken at the level of the painter's nose and mouth. Sharpe found that when lead paint is used in spraying the interior of buildings there is a decided danger of lead poisoning, but in spraying small objects inside a cabinet this danger may be prevented, provided there is an adequate exhaust properly placed, provided the cabinet is deep enough and of proper shape, and provided the object to be sprayed is not too large. If the exhaust is placed above the painter the spray will be drawn up past his face, and if the object is large and the painter stands directly in front of it spraying at a right angle, the spray will roll back toward him in spite of the exhaust.

Sharpe tested masks, respirators, to see how much protection they afforded to men using the spray gun in interior decoration. "Masks of comfortable breathing thickness, moistened with a 5 per cent solution of sodium sulphid, reduced the amount inhaled from 232 mg. per 10 cubic meters of air to 12.4 mg., and a similar mask, but dry, allowed only 11 mg. to pass through. Both these results are still over the danger line"; that is, Legge's limit of 5 mg. per 10 cubic meters of air. (See page 57.) A really effective mask, Sharpe believes, would not let through enough air to allow the man to do his work. Beating the dried overalls after spraying resulted in the recovery of dust containing from 2.79 mg. to 6.02 mg. of lead.

Lead paint is not often used in spraying machines; quick-drying leadless paints with petroleum or coal-tar solvents are the ones chiefly used; and many complaints of ill health are beginning to come from painters engaged in such work. Thus, the Workers' Health Bureau, New York City, reports that benzene was found in 6 out of 16 paints and stains analyzed in its laboratory, and that men handling these mixtures complained of: burning of eyes, dark spots before the eyes or transient blindness when coming into the open air, headache, dizziness, "dopiness," nausea, and various skin lesions, such as acne or redness, swelling and itching, or a pustular eruption.

Lead Poisoning Among Painters.—It is the experience of all countries that lead poisoning is harder to control in the painting trade than in any other, and that while other lead trades show a gratifying improvement the same cannot be said for the painter's trade. The British Factory Inspection Report for 1921 mentions the examination of 217 painters, of whom 31.9 per cent had a lead line, and many a striking lymphocytosis. In the United States there are several studies of the incidence of lead poisoning among painters. Thompson saw in eight years of hospital practice 268 cases of serious plumbism, nearly 75 per cent of which were in painters. The report of the Illinois Commission on Occupational Diseases, compiled in 1911, has 578 cases of industrial lead poisoning which occurred between 1908 and 1910 and of these 157, or 27 per cent, were in painters. The New York Factory Investigation Commission in 1912 gives the records of 109 cases of severe lead poisoning, 42 of which, almost 40 per cent, were in painters, and John B. Andrews (12) studied 60 fatal cases of industrial plumbism in New York for the U. S. Bureau of Labor and 40, or two-thirds, of these were in painters. This shows that the proportion of painters is high among the severe cases and extremely high among the fatal cases. This accords with statistics in other countries, and must not be taken to mean that the painters' trade is the most dangerous of the lead trades, but rather that men remain longer in it. Painters are skilled and well-paid workmen and cling to their occupation as long as possible.

Several intensive studies of groups of painters have been made within the last ten years to determine the proportion of men suffering from chronic lead poisoning. The first was made in Chicago for the U. S. Bureau of Labor Statistics by E. R. Hayhurst (13). One hundred men, members of the Brotherhood of Painters, Decorators, and Paperhangers of America, were examined, and 70 of them described symptoms of more or less pronounced ill-health, 27 giving a history pointing clearly to lead poisoning; that is, they told of one or more attacks of abdominal pain, constipation, severe headache, with or without vomiting, lasting for several days and not accompanied by fever. Nineteen of these had also neuromuscular symptoms such as rheumatic pains, lumbago, sciatica, numbness or paresthesia especially in the arms, muscular cramps and tremors, and two had paralysis. Symptoms of acute plumbism were not found in any case, but indications of chronic plumbism were found in at least 59 cases.

In 1915, Gibson and Apfelbach of the Illinois State Factory Inspection Department, examined 150 painters with the following results: 23 had a history of attacks of acute plumbism; 22 had nephritis; 49 hypertrophied heart, 9 with valvular lesion; 26 had active tuberculosis and 10 latent tuberculosis. In 1918, L. A.

Harris (14) of the New York City Department of Health examined 402 painters, and found 163, or 40 per cent, with definite clinical lead poisoning. He had the urine of 115 tested for lead and 72, or 65 per cent, were positive. In addition, 35 men who had no symptoms of lead poisoning were excreting lead through the urine. The lead line was present, however, in only 22, less than 14 per cent. His search for stippled red cells resulted as follows: out of 103 specimens of blood from cases of positive lead poisoning 13, or 12 per cent, had stippled cells; of 27 suspicious cases, 14.8 per cent; of 19 latent cases, 21 per cent; and of 60 from men apparently normal, only one had stippled cells. Albumin and casts were found in 8.4 per cent of 234 urines.

The histories of 100 painters treated in hospitals for acute or chronic lead poisoning show that painting, being a skilled and well-paid trade, is not lightly abandoned because of sickness. Among these 100 painters, 67 had been employed more than ten years; 35, more than 20 years. Fifty had suffered more than one attack. This is a summary of the varieties of plumbism found in this group:

Acute gastric type without complications.....	33
Gastric with complications.....	49
No gastric symptoms:	18
Nervous only	7
Arthralgia or myalgia	4
Myalgia and palsy.....	3
Arteriosclerosis	3
Arteriosclerosis with palsy.....	1
Total	100

Twelve men had their first attack within three months of beginning work. Nineteen sickened within the first year and all of these had been working inside and using sandpaper. On the other hand, there were six who had worked for more than twenty years before they were aware that they had been poisoned. There were 39 with palsy, which in 14 cases involved more than one limb. Transient acute encephalopathy had occurred in six and three more were suffering from increasing mental deterioration. Eleven had some disturbance of vision, eight had arteriosclerosis with chronic nephritis, and 24 had pains in joints or muscles. The occupations of the hundred painters were as follows:

House painting	56
Carriage and automobile.....	24
Railway car and street car.....	12
Iron painting	4
Sign painting	3
Ship painting	1
Total	100

In 1923 Sharpe (11) of Toronto examined in that city 132 painters, none of whom was suffering from symptoms of acute plumbism, but 13 had a history suggestive of past attacks. Forty had had acute intoxication from turpentine or benzene while working with flat paints, and three while using shellac. Five had been poisoned by wood alcohol and four by benzene or acetone in removing old paint. The record of physical defects and symptoms of ill health among the 132 painters examined are very suggestive of chronic plumbism: tremors, pallor, myalgia, constipation, indigestion, increased blood pressure, headache.

The combined effect of the various toxic compounds with which the painter comes in contact, his liability to accidents and his exposure to cold and dampness, is revealed by the sickness record of a fairly typical branch of the National Union. J. A. Runnberg of the Brotherhood of Painters, Decorators and Paper Hangers, made a report in September, 1921, to the general executive board of the Union which contained a tabulation of the sickness records of one of the Chicago branches, Local 194, for eleven years. This local is composed largely of Scandinavian- and German-Americans. The average membership of the group in the eleven years, 1910 to 1920 inclusive, was 1400. During this period there were 1421 cases of illness with periods of disability aggregating 103,339 days, 283 years. That only serious illnesses are included is shown by the statement that the average duration of illness was 81 days.

There is at the present time an active controversy as to the extent of the danger of lead poisoning in the painters' trade and as to the advisability of prohibiting the use of lead paint altogether. The French are the leaders of the prohibition party, with the Italians following, and their effort to bring about the adoption of this measure by the International Labor Bureau in Geneva has stimulated in Germany and in Great Britain renewed investigations of the dangers of the painters' trade and the harmfulness of certain substances other than lead with which the painter comes in contact. Thus Oliver (5), writing in 1921, questions "whether the symptoms met with in house painters are the result of lead *qua* lead present in paint or are consequent upon the inhalation of vapors arising from the solvents used, such as turpentine, benzin and other spirituous bodies. In exposing animals to the vapor given off from freshly painted surfaces, their health suffered and in exposing others to the vapor of turpentine these animals also suffered and at the autopsy I found the lungs engorged and the tubular epithelium of the kidneys, on microscopical examination, the seat of the cloudy swelling."

Goadby (6) considers that the danger of lead poisoning in painters is caused almost wholly by the dust from dry rubbing of lead paint, and that illness which results from vapors may closely

resemble lead poisoning, yet be due really to volatile thinners. He finds the chief diseases from which the painter suffers are those of the respiratory tract, circulatory diseases coming second and urinary third, whereas if there were as high an incidence of plumbism as is usually held, quite another distribution would be found, for the white lead with which the painter works is not a cause of respiratory disease. The vapors of turpentine, however, and of turpentine substitutes, are known to produce respiratory effects in susceptible animals.

The high blood pressure of painters, higher than that of lead workers, is attributed by Goadby to the vapors of the benzin and paraffin series, while further evidence of the lack of a serious amount of lead absorption in painters was found in the birth rate tables, for painters have a birth rate of 155 per 1000 males under 55 years of age, which is higher than that of professional men and of farmers and graziers. Armstrong (15) also lays stress on the part played by volatile thinners in the illness of painters, and believes that if dry rubbing down were eliminated there would be little danger of lead poisoning in this trade.

In Germany, Lehmann (16) asserts that the hazards of the painter's trade are considerably less than statistics usually represent, and Schoenfeld (17) thinks that an early diagnosis made by examination of the blood smear provides an easy way to arrest plumbism in its incipency, and thus protect the painter.

The French and Italians combat this point of view with much vigor. Thus Ferranini (18) expresses his doubt as to the good faith of these English and German efforts to minimize the dangers of white lead and to attribute the intoxication of painters to turpentine. Clinical and pharmacological evidence shows a great difference between the effects of lead and turpentine, and the greater industrial morbidity rate of painters as compared with white lead workers is not due to the harmfulness of turpentine but to the fact that hygienic measures which can be applied in white lead factories can only with great difficulty be applied to painters. Agasse-Lafont, Heim and Feil (19) examined 21 men who handled only turpentine and zinc white, no lead, and found apparently normal kidneys and high blood pressure in only two, while among 24 men who handled lead there were two cases of albuminuria, and two of high blood pressure. Among 200 painters using lead paint 30 per cent had high blood pressure. They conclude, therefore, that lead and not turpentine is the cause of the kidney lesions and the hypertension of painters.

A very impartial statement of this controversial situation has been made by E. L. Collis (20) of the British Home Office. He says that the question was first raised about one hundred years ago in France where it continued to receive attention from time to time

until, in 1909, a law (which would have come into force in 1914 had not the war intervened) was passed prohibiting the use of lead in paints. Meanwhile other European countries, such as Belgium, Germany, Austria, and Switzerland, had taken more or less stringent action to protect the workers by regulating the painting industry. In Great Britain, where the number of deaths among painters from lead poisoning was observed to equal the total occurring in all factory industries (291 deaths to 280 in the period 1910 to 1921), the question had not been lost sight of; legislation had, however, been aiming more particularly at preventing lead poisoning in factory industries. One result of the intensive campaign so carried out had been to demonstrate that lead poisoning is caused industrially by the inhalation of lead dust, and that other paths of entry for the poison into the body are practically negligible. By concentrating on abolition of the dust risk, the cases of notified poisoning were reduced from 1058 in 1900 to 230 in 1921, even though during these years the disease was placed on the compensation list in 1907 (a proceeding which tended to bring cases to light), and although the number exposed to risk had increased.

Two committees, however, were appointed in 1911 to report upon the use of lead compounds in the painting of coaches and of buildings. Both committees recommended the prohibition of lead paints. The Building Committee held that lead paints could readily be dispensed with for interior painting; while for exterior painting, although lead paints for all purposes could not be replaced by other equally satisfactory paints, they saw no practical means of insuring the enforcement of any code of protective measures and so advised prohibition. At the same time they expressed the opinion that demand would soon bring into existence satisfactory substitutes. The war prevented adoption of their recommendations.

The next step taken was the adoption at the Third International Labor Conference, Geneva, in 1921, of a convention prohibiting the use of lead compounds in the interior painting of buildings, and establishing protective regulations wherever the use of such compounds was not prohibited.

Just before the Labor Conference met, a further Committee on Industrial Paints was appointed to advise the British Government as to the position as it then existed. The report of this committee has now been published. It contains a recommendation that legislation should be passed to give effect to the principles embodied in the convention adopted at the Geneva Conference; but goes no further. The committee differs from its predecessors in not recommending prohibition for the exterior painting of buildings, or for painting coaches and carriages. It based its opinion mainly upon the recent introduction of waterproof sandpaper by the use of which dry rubbing down of painted surfaces can be abolished, and with it the

danger from the dust risk. It maintains that if dry rubbing down is abolished, lead paints can be used with but little risk on the external surfaces of buildings. It also optimistically expresses the hope that the trade may institute inspection within itself of itself in order to prevent breach of regulations, even though adequate government inspection of painting operations upon buildings cannot be established. With regard to coach painting it considers that the safety of the painter can be insured by adequate inspection. Here employers of labor will probably prefer to escape from compliance with an onerous code of regulations by adopting leadless paints.

There can be little doubt that adoption of the recommendations made will mark a distinct advance in the prevention of lead poisoning, even though not so pronounced as if prohibition had been adopted.

Not the least interesting part of the report is that devoted to the effects of turpentine and turpentine substitutes. Evidence was placed before the Committee and also before the 1911 Committees to the effect that painters inhale the vapors of these substances and in consequence suffer from symptoms which have been confused with those of plumbism. That painters do in fact suffer from these vapors is accepted, but, after careful consideration, the committee concluded that "there is not sufficient ground to warrant us in accepting the view that turpentine poisoning is the cause of the leading symptoms commonly attributed to either acute or chronic lead poisoning, nor in attributing to the inhalation of fumes of turpentine and other thinners the occurrence of chronic Bright's disease." While agreeing with the first part of this conclusion, some hesitation may be felt about accepting the second part. Turpentine vapor appears able to set up acute nephritis and repeated attacks might be expected to terminate in chronic nephritis, unless those exposed establish some sort of immunity to vapor. Of such immunity there is no clear evidence.

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CHAPTER 15

MISCELLANEOUS LEAD TRADES

IN grinding paint the danger of lead poisoning comes from dry white lead, sublimed white lead, yellow and green lead chromate and red lead, although the latter is often freshly mixed by the painter each morning as he uses it. The production of pulp-ground or straight oil-ground white lead is very common now, and is quite free from danger of dust. Litharge is used for the production of lead chromate and if handled dry is a source of trouble.

One of the few really dangerous occupations in which women, more often young girls, are employed in the United States is the making of litho-transfer papers for decorating pottery. The colors used are most of them lead colors ground as fine as possible and dusted over prepared paper. The work is now done under cover, but at the time when the Illinois Occupational Disease Commission was making its investigation, E. R. Hayhurst (1) discovered five cases of severe lead poisoning among girls who were doing this work by hand without any protection. As they were between 15 and 17 years of age, they suffered profoundly from the effects. Two underwent an operation of appendectomy because of mistaken diagnosis. One had double wrist drop, double ankle drop and amenorrhea.

Mechanical or commercial artists are a large group of men and women who usually do not know that there is any danger of lead poisoning in connection with their work. I have never seen this occupation mentioned in foreign statistics of lead poisoning and when I inquired about them at the factory inspection office in London I was told that no cases of lead poisoning in artists had ever been reported in Great Britain. The discovery of 15 cases, most of them severe, in the city of Chicago came to me accidentally through conversation with a young artist who had been referred to me by his physician as an unusual case of zinc poisoning. Like most of these artists he supposed he was using zinc white, while really the paint was almost pure white lead; in fact, all but four of the 74 places employing commercial artists were using white lead paint. The paint brushes are of very fine camel's hair and in order to get just the right degree of moisture and to bring them to a fine point the artists put them in their mouths. Besides this they use an "air-brush," worked with compressed air. It sends a cloud of white

paint over the picture and is also used to blow off the superfluous paint after it is dry. Owing to the fact that it is highly skilled, well paid work, the artists are loath to leave it and among the 15 cases there were some of very severe poisoning. The young man I interviewed had been urged by three physicians to have his appendix removed, and a friend of his, for many years in the trade, actually had four abdominal operations before the development of a typical double wrist drop disclosed the real nature of his trouble.

Polishing cut glass of the more expensive variety is done with so-called putty powder, a mixture of oxids of tin and lead. The French factory inspectors regard this as a serious danger and report that 39 out of 200 polishers were affected by the lead; they advised the use of metastannic acid to partly displace the lead. American cut glass is more often finished with hydrofluoric acid, but three cases of lead poisoning in putty polishers were found by the Illinois Occupational Disease Commission in Chicago in 1910.

Brass polishers are frequently said to be suffering from a peculiar form of brass poisoning, which on investigation proves to be plumbism, from the lead in the brass. (See page 277.)

Lead tempering of machine parts, wires, etc., has two dangers,—the fumes from the lead pot, and the lead dust when the cool part is brushed off. Kenney (2) reported a case in a man tempering magnetos who after eighteen months had colic, anemia, general weakness and double wrist drop. Pratt (3) reported no less than nine cases from such a plant although the payroll was of only nine men. The plumbers' trade is not nearly so productive of lead poisoning as it used to be but white lead is still used in "joint wiping," especially on repair work. Among the 560 cases collected by the Illinois, Occupational Disease Commission, 19 were in plumbers, with chronic plumbism of many years' standing.

Lead, chiefly in the form of litharge, is an important ingredient of compounded rubber; sublimed white lead is sometimes used, rarely red lead and the basic carbonate. It is only in heavy rubber goods, gray or black or brown, that lead can be used, because in vulcanizing rubber, sulphur is incorporated and the lead is changed to the black sulphid; therefore white or gaily colored rubber articles, or very thin and light sheeting, does not contain lead. It is used most largely in rubber footwear, mechanical rubber goods, and automobile tires.

Only a few of the employees in any rubber factory handle the lead salts, and it is for this reason, probably, that very little is known about lead poisoning in the rubber industry. Yet a careful search shows that the proportion poisoned is fairly high and among 162 cases of lead poisoning in the Massachusetts General Hospital in 1914, 18, or 11 per cent, came from the rubber factories. This is a very high number as compared with Great Britain which had

only 7 in three years, and none since 1908. In one American factory there were only 25 out of 1200 employees who handled lead, but there were four cases of plumbism in the compounding room, and 7 on the mixing mills. In a second, with 44 men in the compounding and bolting departments there were 15 cases in 1914. In a third, with 22 men compounding and mixing, four acute and 10 chronic cases were treated by physicians in 1913 and 1914. I found altogether 66 cases during 1914, 24 of them in tire works, 9 making footwear, 6 making clothing, 3 druggists' supplies, one mechanical goods, and 20 all kinds of rubber goods.

The lead is used as an accelerator of heat vulcanization and to add weight. Vulcanization by heat, the so-called "open heat cure," is slow and lead is often added to hasten it. Steam vulcanization does not require lead, but lead is often added. In the "press cure" heat and pressure are used in a hydraulic press and lead may or may not be added. There is lead dust in emptying the kegs of compounds, in bolting them, in weighing them, dumping them into a pan and in mixing them with rubber in the mills. One foreman told me that he always emptied twenty-six kegs of litharge at once because although it would "make all the men pretty sick, it was better than to string it along." He had known only one man in fifteen who could stand it without harm. The dustiest work is on the mixing mills, where crude rubber is mixed with sulphur, lead and other chemicals.

A possible source of plumbism is the grinding of old rubber in a reclaiming plant. Hard rubber does not contain lead but old tires and rubber shoes do, and the dust should not be allowed to escape. I submitted two samples of rubber dust, one produced by buffing outer tubes of tires, the other by grinding tires, to the Bureau of Standards of the Department of Commerce. Their report shows that when the Thorpe test with 0.25 per cent hydrochloric acid at body temperature for ten hours was applied, the one sample of dust yielded as much as 6.45 per cent, the other only 0.74 per cent.

Lead wool or lead rope is made by bringing together a large number of very fine strands of pure metallic lead, and twisting them into a loose rope. It is used for calking in large quantities in the construction of gas, water and sewer mains. A similar use for lead is calking the joints of pipes with wedge lead or lead wool, calking the interstices in granite and marble work and in window casings. Telephone, telegraph and electric light cables are surrounded by lead sleeving or conduits. Piano key weights and clock weights and weights for window sashes and dress weights are made of lead. So are the frames of lamp shades and the frames of art glass windows. Piano tubing made of lead is used in organs and player pianos. Artificial silk is weighted with lead.

Among the unusual ways in which white lead is employed must

be mentioned the coloring of shade cloth and coated paper, its use in printing inks (orange mineral and lead chromate are also used), its use as a die lubricant, and its use in making signs and the faces of watches and clocks. Sublimed white lead, lead sulphate, may take its place.

Dr. C. M. Davis (4) of Cleveland tells of an interesting case of lead poisoning, which long went unrecognized because no one suspected that there had been an exposure to lead. The patient was a golf professional who during the winter months spent much of his time repainting used balls, not with a brush but simply working in a handful of white lead paint by rolling the ball between the palms of his hands. He would have attacks of arthralgia and abdominal cramps which were worse always in the spring and which were not improved by the loss of his tonsils and most of his teeth. An unusual amount of work in the spring of 1922 made his symptoms worse and he began to notice the loss of muscular power in his legs. Davis made the diagnosis largely on the history of his occupation and the finding of stippled red blood cells and a mononucleosis of 45 per cent. The diagnosis was borne out by his recovery under appropriate treatment.

An occupation not usually listed among the lead trades is that of the glaziers. These men work in factories which are sometimes ill kept and full of dust. Recently the Workers' Health Bureau of New York City in the course of an examination of a group of glaziers tested the urine for lead and found it in four specimens. The lead is contained in the putties which were found to have sometimes as much as 10 per cent of white lead or even 25 per cent. The men handle these putties with their bare hands practically all their working time, and the dried putty falls on floor and benches and turns to powder and spreads into the air.

It is impossible to give a full list of the occupations in which lead poisoning may occur. Layet (5) said there were 170 in France. From the investigations made by Thompson (6) and by Kenney in New York, by Hayhurst in Ohio, and by the Illinois Commission on Occupational Disease, the following occupations can be listed as those in which plumbism is known to have occurred: Holding lead covered nails in the mouth when cobbling shoes or shingling a roof; giving white shoes a final cleaning with lead white and talcum and benzene; stamping figures for embroidery with white lead, and stamping the lining of shoes with yellow chromate; painting labels on bottles with lead colors; using white lead putty in fastening signs to windows; using white lead paint on umbrella handles and on the pads of brushes through which the bristles are drawn; repairing wooden boxes which have held storage batteries; rubbing white lead into straw hats; polishing diamonds and precious stones; manufacturing linoleum; making and selling wall-paper; tempering machine

parts, piano wires and magnetos; casting picture frames and coffin ornaments; zinc smelting; making artificial flowers; making sodium acetate from the wash water of white lead works; handling lead pipe in an oil refinery; laying lead cables; casting can and car seals.

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CHAPTER 16

ARSENIC

THE literature of lead poisoning is for the greater part industrial, because lead is primarily an industrial poison. Arsenic is used comparatively little in industry and the knowledge we have of the pathology and symptoms of arsenical poisoning is gathered almost entirely from its use as a medicine,—greatly increased of late years by the various anti-syphilitic compounds,—from its use for criminal or suicidal purposes, from the accidental poisoning resulting from arsenical colors in wall papers, tapestries and upholstery fabrics, and from accidental contamination of food and drink with arsenic. The victims of such accidents are often people of the well-to-do classes whose mysterious illnesses are subjected to more careful scrutiny than are those of workers in industry and are more often traced to their real source.

Arsenical poisoning in industry must be divided under two heads: first, poisoning by dust from solid compounds; second, poisoning by the absorption of arsenic in the form of gas. Since these two are quite different in their manifestations they will be taken up separately.

Poisoning by Solid Compounds. *White arsenic, Paris green, Scheele's green, arsenate of lead, arsenic trichlorid.*—White arsenic is also known as arsenic trioxid, As_2O_3 , arsenious oxid, arsenic, acidum arseniosum. When first purified it is amorphous, vitreous, semi-transparent, and is called "arsenic glass"; then, as it takes up water, it crystallizes and becomes opaque, porcelain-like "white arsenic." It is also found as sublimed crystals, or "flowers of arsenic." Paris green and Schweinfurth green are the same, the acetoarsenite of copper, $\text{Cu}(\text{C}_2\text{H}_3\text{O}_2)\text{Cu}_3\text{As}_2\text{O}_6$, containing over 50 per cent arsenic. Paris green is extensively use as an insecticide,* Schweinfurth green, as a coloring agent. Scheele's green is acid copper arsenite (CuHAsO_3), containing 52.8 per cent arsenious acid. It has been much used in Europe as a dye for tarlatan, artificial flowers, calicoes, cretonnes, and wall paper; but it is much less used in this country.

Commercial lead arsenate (1) is usually a mixture of lead-hydrogen-arsenate, PbHAsO_4 , and basic arsenate $(\text{AsO}_4)_3\text{H}_2\text{O}$. At first it was made by reaction between lead acetate and lead

* It is also used in making fireworks.

nitrate, with disodium arsenate, but the most widely used process now is the Luther-Volck, by which lead oxid is suspended in a solution of arsenic acid with a small amount of nitric or acetic acid to act as a catalyzer. This produces lead-hydrogen-arsenate and basic arsenate in proportions varying as the lead oxid or the arsenic acid predominate.

One compound of arsenic which is not now used in industry gave rise to a number of cases of poisoning in England during the war. This is arsenic trichlorid, which was manufactured for purposes of chemical warfare by the action of sulphuric acid on a mixture of common salt and arsenic from which it was distilled over, condensed as an oily liquid, and filled into drums.

In arsenical poisoning, subacute and chronic (the acute form does not occur in industry), Brouardel (2) recognizes four stages.

(1) The first stage is manifested by disturbance of the digestive organs. Vomiting of a blood-stained or bile-stained mucus, characteristically painless and sudden, may occur seven or eight times a day. Constipation is more common than diarrhea. There may be a slight rise of temperature and a rapid pulse rendering the diagnosis more difficult. This first stage is of short duration and is succeeded by (2) the stage of skin eruptions and laryngo-bronchial catarrh. In a widespread epidemic of slow arsenical poisoning studied by Brouardel, the prevalence of this latter feature led the physicians to think that they were dealing with an epidemic of influenza. There was hoarseness very commonly, loss of voice in some cases, coryza and severe conjunctivitis in others. The skin lesions consisted in redness and swelling of eyelids and of scrotum, and in erythema over the whole body, with scaling, loss of nails, loss of hair, and brownish pigmentation. (3) Disturbances of sensibility then developed; obstinate headache; numbness; stiffness; and sensations of crawling or prickling in toes, feet, legs, with painful cramping of the muscles. Anaphrodisia was present in all of Brouardel's cases. (4) Motor paralysis came on much later, developing gradually. There was difficulty in going up stairs, the feet dragged in walking; then it became impossible to walk without some support; then impossible even to stand. Death comes by paralysis of the heart.

The cases of Brouardel which formed the basis of this description were not industrial, but the histories of industrial poisoning of a subacute or chronic type have in general the same features. It is Brouardel's second stage, affecting the upper respiratory tract and skin, which is most often seen in industrial cases. The powder that reaches the throat causes the pharyngitis and laryngitis so characteristic of arsenical workers, who almost always have hoarse voices. Breathed into the nose, the effect is on the mucous covering of the septum.

According to Dunlap (3), the arsenic men—furnace tenders, loaders, refiners, dumpers, railway men, etc.,—who recover more or less pure arsenic trioxid from the flue dust of the Anaconda copper smelters, have a form of slow inflammation of the mucous membrane covering the septum, which results in sloughing, then in necrosis of the cartilage from loss of blood supply, then in sloughing of the cartilage and perforation which heals leaving no deformity, since it never involves the bone. It begins with a white elevated spot at Kiesselbach's area, and if at this stage the man is careful to protect it with a bland ointment (Dunlap recommends camphor-menthol-petrolatum) it will not progress; but if he neglects it, necrosis and baring of the perichondrium and then of the cartilage follows. When perforation has occurred, the cartilage is seen flush with the swollen edges of the mucosa, which are gray, edematous, and crusted. This condition is distressing because of the obstruction and the hard crusts, but abscesses do not develop even under the everted edges, probably because of the free drainage. The entire process, ending in spontaneous healing with loss of cartilage, takes from six months to three or five years. During the stage of obstruction in the nares with consequent mouth-breathing, the inflammation in throat and larynx may be distressing, and there may be soreness of the tongue and excessive salivation; but all the symptoms are local, and systemic poisoning does not seem to occur. The same thing was true of two similar cases described by B. F. Davis (4) of Chicago, in a chemist and his assistant who had been grinding 20 to 30 pounds of arsenic trioxid daily for six months. In Paris green work, also, the lesions suffered by the men are almost always confined to the skin and mucous membranes; yet there was a fatal case of typical acute arsenical poisoning in a Paris green packer reported by the Illinois Factory Inspection Department in 1913.

Undoubtedly in industrial arsenical poisoning from dusts, the most common and troublesome feature is the production of various skin lesions. In poisoning from large amounts of dust, such as are encountered in packing Paris green and lead arsenate, and in handling the flue dust of copper and lead smelters, the effect shows itself in inflammation of the eyelids and conjunctiva; in redness and swelling of the scrotum, followed by ulcer formation; in inflammation of the skin of face, hands, and feet, of axilla and groin, and wherever the dust lights and perspiration favors its action. The attempt to protect the workman by respirators has always failed; because where the edge of the respirator presses on the cheek the skin grows moist and the powder is caught, and in consequence a row of ulcers forms.

The mildest form of skin disease is hyperidrosis, *i.e.*, sweating of palms and soles, loss of hair, trophic changes in the nails, and

scaling of the skin. Then come papular or vesicular eruptions more or less severe, sometimes with large blebs filled with bloody serum. Infection changes these lesions to ulcers; and Paris green workers complain especially of ulcers of the scrotum, lips, eyelids, and nostrils, and even of the feet if their boots are leaky. But the typical skin affections caused by long-continued absorption of arsenic consist in patches of scleroderma or warts or horny patches with diffuse brown or grayish pigmentation, melanoderma. The palms and soles are first affected and most extensively involved; but there may be twitching and stiffness of the face, obliterating wrinkles and giving a mask-like look; and the skin may have a curiously smooth, silky feel. The hard patches on palms and soles crack, and fissures form, the fingers may be stiff, and fine work impossible.

The pigment of arsenical melanoderma contains no arsenic. It is deposited in the lymphatic channels of the papillae of the cutis vera and is the product of blood destruction, resembling bilirubin. It is seen on the neck and face, around the nipples of the breast, over the lower abdomen, or as a border around the patches of scleroderma, or in some cases distributed generally over the body. Scleroderma is more often a manifestation of arsenical poisoning than has been supposed, as is emphasized by Ayres (5), who found arsenic in the urine of three consecutive cases of scleroderma at the Massachusetts General Hospital. One of the cases was of a man who a year before had noticed that his right hand was weak, and that bowling balls would fall out of his fingers, which were slightly stiff. His palms and the soles of his feet were sore. He was treated for flat-foot, but with little relief and six months later the soreness and stiffness increased, his hands were swollen in the morning, and perspired a great deal. Sometimes there was pain in the hands on pressure or contact; and in cold weather they would turn white or dusky, and ache. When questioned, he stated that all the joints of his hands were stiff after inactivity, and his fingers constantly fixed in slight flexion. He had begun to be restless at night and had lost weight. There was no soreness of the eyes, tongue or throat, and no gastro-intestinal involvement.

Examination showed typical scleroderma with diffuse brown pigmentation involving hands, forearms, chest, and abdomen. The palms were wet with perspiration. Nothing else of importance was found except a moderate anemia, 80 per cent hemoglobin. The urine was negative for lead, but positive for arsenic; and arsenic was also found in the glazed paper which he handled in his work.

That long-continued absorption of small quantities of arsenic may be followed by the formation of epithelial new growths, was asserted in 1887 by Jonathan Hutchinson (6), and many subsequent observations have confirmed his view. Bland-Sutton (7)

classes arsenic as one of the auxetics in the strict sense, a substance which can provoke changes in the epithelial cells so as to predispose them to become cancerous. Leuenberger (8) also places arsenic high in the list of bodies which favor the development of new growths. Dubreuilh (9) described in 1910 four cases of arsenical keratoma which illustrated Hutchinson's theory, and called this one of the most characteristic and serious of the effects of arsenic. He collected 19 histories of epithelioma, following protracted administration of arsenical compounds; but none was of industrial origin. Von Geyer's three cases, which he reported to the International Congress of Medicine in 1900 at Paris, were only indirectly industrial. They had occurred in the village of Reichenstein in Upper Silesia where the well water was found to contain arsenic which was traced to the fumes from smelters working up ores rich in arsenic. The fumes settled on the land and the rain washed the arsenic into the wells. Among the 31 cases collected by Nutt, Beattie, and Pye-Smith (10) there were two of industrial origin, those of men who were employed for twenty years in a factory making arsenical sheep-dip. They carried the full sacks on their shoulders, and in one man the epitheliomatous growths appeared on the neck, in the other, on the shoulder and chest wall.

As long ago as 1878 Härting and Hesse (11) asserted that there was an unusually large number of cases of lung carcinoma among the miners of the Schneeberger cobalt arsenide mines in Saxon Switzerland, and they linked it up with the arsenic. Arnstein (12) took up the matter again in 1913, reviewed the scanty observations which had been made, and went into the region to make a personal investigation. He found that 44 per cent of the deaths among these men were attributed by the physicians of the region to malignant tumor of the lungs, but that the diagnoses were not confirmed by autopsies. He himself examined 70 miners and found in about half, signs suggestive of tumor, namely parasternal and paravertebral dullness; but he could secure only two autopsies, and one of these proved to be caseating tuberculosis. The other showed a squamous-celled carcinoma, originating in the right lung, with extension to pleura and pericardium, and with metastases resembling lymphosarcoma in lymph glands, liver and spleen. He found that Schmorl of Dresden had had two cases of round-celled sarcoma and one case of carcinoma in Schneeberger miners in recent years.

According to Teleky (13) there has recently been an investigation by a special commission, appointed to look into the incidence of lung cancer in the miners of Saxony and the unusual prevalence of such new growths in the hospital population of Dresden, the nearest medical center. They have established the fact that Schneeberg miners still suffer from pulmonary cancer to a considerable extent. Their occupation seems to bring about a predisposition to malignant

growths in the lungs, but there is no uniformity in the structure of the growths.

Efforts have been made to trace the skin cancer caused by soot, pitch, and paraffin, the so-called chimneysweeps' cancer and briquette makers' cancer, to the arsenic present in the coal. British coal is especially rich in arsenic, and England is especially the home of chimneysweeps' cancer. Délépine, working in 1903 for the British Royal Commission on Arsenical Poisoning found in one sample of coal 5.8 grains of As_2O_3 per pound, and in another 28 grains. The epidemic of arsenical poisoning from beer in Halifax in 1902 was traced to drying the malt in air heated by burning coal which contained arsenic.

The presence of arsenic in coal soot was emphasized by Crafts (14) of Boston in 1891, at a time when Boston physicians were hot on the scent for all possible sources of arsenical poisoning. He says that English coal is especially rich in arsenic which accompanies the sulphur, and that the dust from chimney flues has been found to contain much arsenious acid.

A very vigorous stand in favor of this theory of the causation of briquette makers' cancer is taken by two Belgians, Bayet and Slosse (15), who found in one briquette factory no less than eleven out of 30 men with skin lesions, three of them cancerous. These lesions were not typical keratomatous plaques on soles and palms, as described by Hutchinson, but carcinomatous degeneration of warty growths. The resemblance to arsenical cancer was seen, however, in the fact that the growths were multiple, and developed early in life; and final proof was furnished by the discovery of arsenic not only in the coal, soot, dust, and briquette mixture, but in the urine, hair, and finger nails of the workmen. Control tests made in the villages among other workmen gave negative results. Bayet and Slosse hold that they have proved the arsenical nature of the keratosis, warts, and cancer of briquette makers, and that the English cases of chimney-sweeps' cancer and the epithelioma of English briquette makers, is to be traced to the arsenic in English coal.

These views are rejected by both German and English authorities. Thus Burkhandl (16), reviewing their findings, points out the small number of cases on which they are based, the lack of any statement as to the quantity of arsenic recovered from blood, urine, hair, etc., and the fact that the lesions resembled tar cancer and not the ulceration and scars which are seen in arsenic smelters who for years are exposed to arsenical dusts. According to him Lehmann found no evidence of epithelioma among the Dutch and Belgian workmen who handled zinc white containing 0.4 per cent arsenic. In England Leitch and Kennaway (17) tried to produce experimental carcinoma in rats and mice by administering arsenic through

the mouth and on the skin, but they were successful in only one animal, after applying potassium arsenite to the skin. They do not believe that arsenic plays a causative rôle in the cancer of pitch and soot workers.*

Next to the skin lesions the most outstanding feature of chronic arsenical poisoning is multiple peripheral neuritis, with sensory, motor, and trophic disturbances. The sensory symptoms are the most striking; indeed Seeligmüller (quoted by Marik (18)) says that a characteristic of this form of arsenical poisoning is the marked sensory disturbance and the slight motor paralysis. In the early stages there are various disturbances of sensation, prickling, numbness, a feeling of coldness and stiffness in the hands, which "feel as if they did not belong to me," and dulling of the sense of touch in the soles of the feet so that the patient cannot distinguish between a wooden and a cement floor. Headache is common and may be very severe. In one of Seeligmüller's (19) cases, a taxidermist, a raging headache came on whenever he received a consignment of arsenic-cured skins from Africa. The neuralgia may be so severe as to throw all other symptoms into the background. It is not affected by motion, is much worse at night, starts usually in the feet; and, because it is often accompanied by numbness, Marik called it "anæsthesia dolorosa arsenicalis."

Motor palsy is usually bilateral and symmetrical. Descriptions of motor paralysis in arsenical poisoning are rare in the literature, according to Marik who collected all the cases he could find up to 1891, and added two of his own, but they were non-industrial. Even the textbooks do not give much space if any to it. Brouardel (2) was the first to describe arsenical palsies in subacute poisoning, and his cases were not industrial. French seamstresses, working on green tarlatan dresses, are said to have suffered from this form of poisoning, but as a usual thing industrial arsenical poisoning is not accompanied by palsy. Hirt says that anything more than paresthesia or neuralgia is very rare.

The palsy is likely to affect the long extensors of fingers and toes, as does lead; but it is distinguished from the latter by the severe neuralgic pains and by the greater tendency toward a multiple symmetrical neuritis. A claw-like hand sometimes results.

Finally, in some non-industrial cases of chronic arsenical poisoning, there has been demonstrated an effect on the optic nerve, an optic neuritis; which is, according to de Haas (20)† and his findings have recently been confirmed by Elzas (21), to be traced in these

* For a discussion of the theory that the bladder tumors of anilin dye workers are caused by the presence of arseniuretted hydrogen fumes in the air, see *Journ. Indust. Hyg.*, 1921-22, 3, 16.

† In 55 out of 58 patients with inflammatory changes in the retina and optic nerve, arsenic was isolated from the urine, which contained an average of 13.7 mg. per litre.

instances to slow arsenical poisoning from wall papers and tapestries and upholstery dyed with arsenical colors. One such case has thus far been reported from industry by Moleen (22) who describes skin lesions and optic atrophy caused by the use of arsenical insecticides. The man first noticed "blistering" of the hands, then irritation of the nostrils, then diplopia lasting a few months and disappearing, to be followed by blurred sight in both eyes, and then finally by loss of vision. Both disks showed marked atrophy and marginal degeneration.

One of Ayres' (5) cases illustrates what has been noted by others also, that an attack of arsenical poisoning seems to leave the victim peculiarly sensitive to this substance. This was a woman, who five years before had sprayed fruit trees with an arsenical preparation and had a very severe generalized papular eruption, with blood-filled vesicles, digestive disturbances, sore mouth and tongue, salivation, loss of weight, muscular weakness, amenorrhea, painful urination, rapid heart, paresthesias, headache. These symptoms in slighter form returned more or less every year after, being always worse in late winter and early spring. The cause was found in a supply of Paris green which was kept in the kitchen, tiny amounts of arsenic keeping up the poisoning of five years back.

The diagnosis, according to Kobert (23), depends largely on the discovery of arsenic in the environment. The detection of arsenic in the urine is of great assistance. This was emphasized by a group of Boston physicians under the leadership of J. J. Putnam (24) who in the nineties of the last century called attention to the danger of poisoning from arsenical colors in wall paper and fabrics, especially in a damp house. Ill-health with marked disturbances of the central nervous system were traced to the arsenic given off from paper and fabrics, and arsenic was found in the urine of the patients.*

Many of the earlier reports of the discovery of arsenic in the urine of patients are unsatisfactory, because no proof is given that the reagents used were free from this element (Hills (25)).† However, those of Putnam, Sanger (26) and Hills, all of Boston, seem to have been beyond cavil, and they found quantities varying from 0.005 mg. to 0.1 mg. in a 24 hours' specimen (Putnam), from 0.002 to 0.068 mg. (Sanger), and from 0.003 to 0.3 mg. (Hills). The length of time taken to rid the body of arsenic was, in a case of Wood's, 93 days after the dose was taken; in Sanger's wall-paper

* Putnam's work aroused a great deal of attention and a number of articles followed dealing with this hitherto unsuspected source of arsenical poisoning.

† The difficulties inherent in accurate tests for the presence of arsenic are illustrated by an article recently published by the Federal Public Health Service, on arsenic in supposedly pure zinc. Eight samples of zinc sold as "chemically pure," "arsenic-free," were all found by Myers to contain arsenic, as much as 1-10 parts per million of zinc, arsenic estimated as metallic.

cases, the urine was free from arsenic after 19 to 140 days; in Hills' from 23 days to more than 80. Recently Ayres, working also in the Massachusetts General Hospital, found arsenic in the urine in 12 out of 25 specimens.

Wignall (27), of Manchester, who is physician to one of the great British dye works, has of late made it a rule to test for arsenic the urine of men engaged in certain processes in which arsenic in vapor form may be present. (See page 228.) He found amounts varying from 0.07 mg. to 0.796 mg. per 100 c.c. of urine.

Brouardel and Pouchet (2) found arsenic in the hair and nails of all who died of the poison; Legge (28) found it in the hair of men engaged in making arsenic trichlorid; and Bayet and Slosse (15) found it in the hair, nails and urine of men working with arsenical pitch. According to Brouardel's experiments with dogs, arsenic remains longest in the spongy part of the bones, and next longest in the brain. In one dog he found arsenic in the bones 143 days after the administration had stopped.

Arsenic increases the resistance of the red blood corpuscles to hemolysis (Hill (29)). Gunn (30) also showed that he could raise the resistance of these cells, not only to hypotonic salt solution but to hemolysins, by immersing them in 1/10,000 arsenious acid for an hour. Giordano (13) says that he tested by Ribierre's method the blood of eight men who had been poisoned by hydrogen arsenide fumes, and found the globular tension increased.

Arsenic in Industry.—Arsenic is very widely distributed in nature; for it is found together with almost all the sulphids of the heavy metals; and since most of the metal ores are sulphids, it follows that arsenic must be present in the greater part of the material which is mined and smelted or reduced. Only the ores of quicksilver are arsenic-free. Iron pyrites or iron sulphid is the commonest iron ore except the oxids; galena, or lead sulphid, forms the greater part of the lead ore which is mined at present; and zinc, copper, and antimony also exist in nature chiefly as sulphids. All these ores carry arsenic as an impurity, and sometimes a very large proportion. For instance, the flue and bag house dust of the lead smelters in Utah and Colorado may contain as much as 60 per cent of arsenic. The widespread epidemic of "sore nose" among the horses on the Montana and Utah ranges was traced to the arsenic-containing smelter smoke, which settled on the grass of certain valleys to the leeward of the smelters.

Industrially arsenic is recovered from the flue and bag house dust of the western lead smelters and copper smelters. According to Dunlap (3) of the Anaconda Copper Company of Montana, the volatile gases given off in smelting copper are chiefly arsenious oxid and sulphur dioxid, which pass through flues to deposit as dust and contain some 20 per cent arsenic. The solid particles are pre-

cipitated by the Cottrell method and then are shaken to a hopper below. This dust goes through a second furnace and a second Cottrell precipitator, the product from which is 75 to 90 per cent arsenious oxid. This is sold as a "weed killer"; or it is purified in a refining furnace and sublimed in a "kitchen" as a fine white powder, 99 to 100 per cent pure. Some of it forms in lumps which must be ground. The men on the furnaces, the refiners, loaders, railway crew, dumpers, kitchen wheelers and barrel packers, all come in contact with arsenic dust.

The trioxid, or arsenious oxid, or white arsenic, is used together with sulphur and caustic soda or potash for sheep dip, and similar mixtures are used to preserve hides and skins of birds and animals. Barton described typical arsenical neuritis in a taxidermist* and in his wife. (See Kobert (23).) Rambousek (32) says that arsenical poisoning occurs in Germany among men in the tanneries who handle hides from South America which have been treated in this way, and there were some English cases among men unpacking bird skins. W. Gilman Thompson (33) reports a case of arsenical poisoning, peripheral neuritis, in a tannery worker, and says that an American chemist found arsenic in 11 out of 42 samples of furs, sometimes as much as 170 grains to the square yard. Hayhurst (34) found it as an ingredient for glass compounding, in powder form, one Ohio glass factory using as much as two tons of arsenic trioxid in a month. Another use in this country is as antifouling paint on the bottom of ships, the arsenic liberated by the action of the sea water killing the barnacles. Apparently this is also true in England; for among the industrial cases given by Legge is one in a man who was chipping paint off a ship. Legge's cases, which are for the years 1900 to 1913, are as follows:

Making emerald green.....	46
Extracting arsenic	8
Making sheep dip.....	5
Paint manufacture	4
Chemical works	3
Smelting lead and zinc.....	3
Sorting bird skins.....	3
Wall paper manufacture.....	2

There were also one case each in making shot, scraping paint off a ship, tanning, and unloading white arsenic.

* A Chicago taxidermist described to me his method of procedure. He adds a pound of white arsenic to a gallon of water, together with soda, and boils it in the open air till it is dissolved. In this he soaks the feather coats of birds, and then while still wet he fits them over the stuffing; for shaping can be done only while it is wet. Skins of animals are first treated with salt and water, then with this same solution of arsenic. He does not think that the arsenic is irritating to the skin so long as it is in water, he himself never having had any form of skin disease while in this work.

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Paris green, aceto-arsenite of copper, is used enormously in this country and considerably in England for spraying. The production consists in precipitating lead acetate or lead nitrate with sodium arsenite; but it is not till the drying stage that there is much danger of trouble. This is the most important arsenical industry in the United States. Legge found a good deal of arsenical poisoning among Paris green workers in a London factory in 1900, no less than 20 out of 33 men having to be suspended on account of the effects; but some 13 years later only 0.6 per cent had to be suspended, improvements in that time having so reduced the dust that there was almost no exposure. Nevertheless the weekly medical examination was kept up; for so long as there is any exposure at all there will be some cases.

The two centers for Paris green manufacture in the United States are Brooklyn and Chicago. Bulletin 83, July, 1917, issued by the New York State Department of Labor, describes an examination of 42 workers in Paris green, 21 of whom had ulceration or furunculosis or irritation of the nasal mucosa, or conjunctivitis, and in addition three showed marked anemia. The Paris green plants in Illinois employ a very fluctuating force of workmen, varying from some 12 in October to 561 in March. Few men remain in the work long, therefore; and it is one of the industries in which a rapid labor turnover makes for the protection of the men against poisoning.

The report of the Illinois Factory Inspection Department for the years 1912 to 1916 have several items on arsenical poisoning. They note that scrotal ulcers are quite common among the men working in Paris green. Six cases of poisoning from Paris green, and two from lead arsenate, are noted in one year; 20 cases in another year; this being from a force that varied between 16 and 178. Two of these cases had ulcerative pharyngitis, two conjunctivitis and inflammation of throat and nose, the others colic and constipation. It is noteworthy that the poisoning which occurs in Paris green workers is usually confined to the skin and mucous membranes, although rarely a case of systemic poisoning may appear as in 1913 when Apfelbach of the Illinois Factory Inspection Department made an autopsy on a very rapid case of arsenical poisoning from this industry, the man dying after less than two weeks' exposure. Koelsch (35) finds it to be true of all the solid arsenic compounds, that the form of poisoning is rarely severe. In many years' observation of the Schweinfurth green manufacture of Bavaria he has seen only skin lesions.

It is excessively hard to protect the workers in Paris green. The powder is very light and fluffy, and mechanical packing has so far been impracticable. No protection can be worn which makes the skin perspire, for that only increases the danger of ulceration. Respirators do this by pressing on the skin and making it moist,

and so rubbing off the surface cells. The procedure generally adopted is to plug the nostrils lightly with cotton, to plug the ears in the same way, and to smear the face over with some bland ointment. Then a full shower bath must be taken at the end of work and the work-clothes must be clean each day. Even with all these precautions, protection against skin irritation is not sure.

The Federal Public Health Service has lately been using Paris green in killing anopheline larvæ. According to Dr. M. A. Barber it is used only in solution of about one per cent and out of doors; and no trouble has occurred in connection with it. In using it against the boll weevil there have been complaints of bronchial irritation, minor digestive disturbances, and sores on the skin. In the use of calcium arsenate, which is now common in the South, only one of the experts in the cotton states whom Barber consulted had heard of any serious trouble. He had seen some rather serious chronic arsenical poisoning in Louisiana, following long and intimate contact with these parasitocides.

An increasingly popular insecticide is lead arsenate which is taking the place of Paris green more and more. At first it was packed and sold as a paste, and there was little poisoning from it, in the plants where it is produced, but because of the weight of the paste they have of late begun to dry it and pack the powder, greatly increasing the danger. From reports which have come to me, the poisoning from it is lead poisoning, not arsenical, but one of Ayres' (5) cases of scleroderma, with arsenic in the urine, was in a woman who had a small shop and who had for years kept powdered lead arsenate on her shelves to kill mice. Another had used lead arsenate sprays in gardening.

The German Factory Inspection Reports describe a new way of using arsenic as a parasiticide in the pine forests of Potsdam. Compounds containing arsenic acid are heated to 2000° C. and the vapors released. The iron container is half buried in the ground, the cover is taken off, a fuse is lighted, and then the worker departs. The vapors spread for about 20 to 30 meters. Three men who were carrying back a closed container were poisoned by the fumes because the cover came off and for some reason the reaction started up again before they could close it securely. One of them died after six days' illness.

Arsenical colors are not nearly so much of a danger as formerly. In the early days of anilin dye manufacture, arsenic was used as an oxidizing agent in making the fuchsin group of dyes; and these colors then contained varying amounts of arsenic, so that a strong popular prejudice arose against anilin dyes because of their undeniable poisonousness. That method was abandoned years ago and the only arsenical colors now used are Schweinfurth green (rarely) and Scheele's green, which is still used in dyeing fabrics,—especially

tarlatan materials for artificial flowers, and wall papers. The danger from the use of arsenical color in wall papers is due to the curious property of a certain mold, *penicillium brevicaulis*, which is likely in damp houses to grow in the paste used to apply the wall paper, and which decomposes the arsenic in the coloring matter and liberates it in the form of a highly poisonous gas. This was formerly supposed to be arsin or hydrogen arsenid, but is now held to be diethyl arsin.*

In the older countries wall paper is still colored with arsenic green, as is evident from recent English Factory Inspection Reports which speak of arsenic poisoning in men making wall paper, and by the cases recently published in Holland by de Haas (20); but in this country it seems to be a thing of the past. The Massachusetts law, passed in 1900, limited the amount of arsenic in wall paper and textiles not used for clothing to 0.1 grain per square yard, for textiles used for clothing to one-tenth of that; and in 1904 a report of the U. S. Department of Agriculture stated that analyses had been made of 537 samples of wall paper and only four had over 0.1 grain. Legge (28) says that wall-papers examined for the London Medical Society were found to contain from one to 50 or 60 grains per square foot.

The danger from arsenic used in other kinds of paper is shown in the history of a case from time to time. Thus, Kobert (23) says that in Switzerland in 1889 a number of bank clerks were poisoned by handling money printed with arsenic green, and Cutler in 1890 described a typical case of multiple neuritis in a man who held green labels in his mouth. The case of scleroderma from Ayres' report, given in abstract above, was in the foreman of a paper manufactory, who for 10 years had handled glazed paper. When arsenic was discovered in his urine, Ayres looked for its source and found it in three of four samples of paper from the factory.

A new compound used during the war, arsenic trichlorid, caused several cases of poisoning in England. The escape of the vapors produced an intense irritation of the skin, eczematous ulceration of the face and hands and other exposed parts, and of the mucous membrane of eyes, nose, throat, and bronchial tubes. One man died as the result of an extensive burn on the leg, and death was found to be due to absorption of the arsenic which was found in considerable quantities in the various organs. According to Legge, "poisoning from this compound resembles that caused by other salts of arsenic, and is quite different from the form produced by inhalation of arsin gas; although it must be noted that the pathological changes in liver and kidneys have a good deal of resemblance." †

* See Glaister, J., *Poisoning by Arseniuretted Hydrogen or Hydrogen Arsenid*, Edinburgh, 1908, Chapter X.

† What may be regarded in a way as a form of industrial arsenical poisoning is the intoxication of physicians and attendants who administer arsenical, anti-

Hydrogen Arsenid, Arsin, Arseniuretted Hydrogen, AsH₃.—This is a highly poisonous gas, differing markedly in its action in many respects from the solid forms of arsenic. It is a powerful blood poison, causing destruction of red corpuscles, and the early symptoms are those of anoxemia, the later are due to the presence in the circulation and organs of the products of disintegrated red cells. The first symptoms come on usually a few hours after the gas has been inhaled, but if the dose is very small there may be an interval of one to three days. In light cases, nausea and headache come on in a few hours, and may pass off with no further trouble; but usually, even in mild cases, there is shivering, exhaustion, dizziness, pressure in the epigastrium, vomiting, perhaps abdominal distension and diarrhea,—in short, all the symptoms of acute anoxemia. Evidence of the destruction of the red corpuscles is seen in the color of the urine, which within the first 24 hours appears dark, sometimes reddish, or even a deep Burgundy red. In several cases it has been the color of the urine which has first given alarm to the victim of the poisoning.

The vomiting, pressure in the epigastrium, pains in the back, weakness and prostration, have in instances of widespread intoxication led to a diagnosis of food poisoning, as in the cases occurring in a British submarine and in Italian submarines (see page 227), and also in Koelsch's cases which occurred in a vanadium-steel works in Germany. The color of the urine and the presence of albumin in the urine, as well as the blood count and the appearance of jaundice in the later stages, pointed to a hemolytic toxin. According to Kobert, hydrogen arsenid is the only industrial poison of importance belonging to the hemolytic group.

Glaister's book on arsenic gas poisoning, published in 1908,* contains a great deal of information on this form of industrial poisoning. He reviewed 40 cases from the literature up to that date, and added 7, tabulating the main facts as to source of poisoning; clinical history; duration of sickness; examination of blood, urine, feces; outcome; autopsy findings; and isolation of arsenic from organs and fluids. He gives the symptoms of acute poisoning in the order of

syphilitic remedies. According to Slosse (15), tests made by Strzyzowski's modification of the Marsh test, showed arsenic in the blood of four out of six individuals, while normal controls showed none. Samples of cleaned and degreased hair from these individuals were examined and arsenic was found in one gram while it cannot be detected in one gram of hair from normal persons. As little as 0.05-0.3 gm. was sufficient to give a positive test in nails. Hippuric (A) and glycuronic (B) acids in the urine were higher than normal, which is taken to indicate the presence of the benzene part of the arseno-benzenes in the organism. Tests with respired air showed that the substances were not absorbed in this way, but a normal patient in whose socks arseno-benzene was placed showed a rapidly increasing amount of urinary A and B and gave a positive blood test, showing that absorption took place through the skin.

* Poisoning by Arseniuretted Hydrogen or Hydrogen Arsenid, by John Glaister, Edinburgh, 1908.

their appearance as follows: (1) an indefinable feeling of illness and of great weakness, (2) giddiness and faintness, (3) pains in head and epigastrium, (4) coldness of body, (5) sense of oppression of breathing accompanied in some cases by some measure of cyanosis, and (6) nausea and vomiting.

These are quickly followed by continuous vomiting, at first of bilious matters, and later of bloody material; jaundice, which may vary in tint from golden yellow to mahogany, ranging through coppery, bronze, and mulatto tints, and which extends usually over the whole body, but which in lighter cases may be located solely in the conjunctivæ; thirst and dryness in the throat with weakness of the voice; pains in the loins; pains or a sense of fullness over the region of the liver; hemorrhages from one or more different parts of the body; hemoglobinuria, or hematuria, or oliguria, and in cases going on to a fatal termination, anuria; and yet there may be clear mentality, with sometimes minor degrees of stupor, although generally before death supervenes there is some measure of unconsciousness with or without delirium.

In addition to these symptoms, and mostly toward the end, hicough and subnormal temperature are found, while physical examination of the body of the patient will reveal in most cases enlargement of the area of dullness of liver and spleen. Probably the most outstanding symptoms, and those which would lead to a suspicion of poisoning by this gas, especially where there is a history of exposure to gaseous emanations, are the following: severe nervous shock, bloody urine, jaundice of a more or less coppery color which quickly supervenes, and alterations of the blood as seen on microscopic examination. The anemia may be rapid and extreme. Glaister's cases, 28 and 1, had counts of 1,800,000; and in case 16, the reds numbered only 885,000.

Experiments carried on with hydrogen arsenid by the Chemical Warfare Service (36) showed that dogs did not manifest any symptoms while in the gas chamber, but they did an hour or two afterwards. It was found that AsH_3 differs from all other arsenic compounds in having a strong affinity for hemoglobin resulting in hemolysis and, following this, in icterus and hemoglobinuria. A very marked secondary anemia comes with the onset of hemolysis.* In 72 hours the reds may fall to 2,000,000 or to 1,500,000 and there is stippling, poikilocytosis, anisocytosis, normoblasts, and a few megaloblasts. There is moderate polymorphonuclear leucocytosis.

* Wislocki (36) quotes an unpublished statement of Mackenzie on the basis of some experiments to determine the nature of the hemolysis in arsin poisoning: "Upon entering the blood stream, arsin is taken up by the hemoglobin of the red blood corpuscles, forming a compound which imparts a brownish color to the blood. In the presence of the oxygen in the corpuscles the arsenic-hemoglobin compound is gradually converted into arsenic oxid, and during this process of oxidation, hemolysis takes place."

Arsin is an intense hemolytic agent and hemoglobin may appear in the urine after a latent period of only 4 to 6 hours. Death may occur from acute hemolysis. If the action is slower, the liver is overtaxed by disintegrated reds, bile is formed in excess of the rate at which it can be excreted, and jaundice results. At autopsy, the blood is brownish and fluid, the spleen is enlarged, and a dull brick red, the liver is large, yellowish red, and flabby, the gall-bladder is full, the kidneys large and blue black. The blocking of the tubules causes casts and, if it is extreme, suppression of urine. Acute cases which recover have anemia which persists for some time, but no permanent lesions.

Stadelmann (37) found granules of detritus of red cells in the kidney, hemoglobin in the urine, also some red cells; and the spectroscope showed hematin or methemoglobin, but in small amount. The gall-bladder is full of very thick bile, as are also the bile ducts, with an amorphous sediment of bilirubin and crystals. The bile is too thick to flow out and is resorbed, arsenical jaundice being a resorption, hepatogenous jaundice. The serum may contain hemoglobin (Stadelmann, Giordano). In dogs Stadelmann found the bilirubin rising from 0.05 per cent to 1.0 per cent while at the same time the quantity of bile fell from 147 to 26.

There are different statements as to the quantity of AsH_3 which may be fatal in a human being. Dubitsky (see Koelsch (35)) from his experiments on cats, whose fatal dose is 5 mg. per kilo of weight, reckons that for man 30 mg. would be fatal; but Joachimoglu (38), who tested the hemolytic action of the gas on red corpuscles, estimated the fatal dose at 0.1 to 0.15 g. (100 to 150 mg.). Erben (39) quotes Schindler as having seen poisoning follow 0.01 g. (10 mg.); while on the other hand Taylor (see Koelsch (35)) saw a man who survived for six days the inhalation of 70 mg. Rambousek says serious symptoms follow the inhalation of as much as 1/100 of a milligram.

Dubitsky finds the concentration a detail of importance and says that the danger begins when the air contains 0.05 parts per 1,000 and that even 0.03 parts per 1,000 will produce poisoning after several hours.

According to German statistics the mortality is not so great as is generally supposed. In Heffter's (40) list of 116 industrial cases there were 33 deaths, or 28.4 per cent; but the 14 added more recently by Koelsch make 130 with 36 deaths, a mortality of 27.7 per cent. Rambousek described 30 cases, 19 of them fatal; and of Glaister's 118 in whom the outcome was known, 37 died, making 31.3 per cent.

Legge says (28), in commenting on the cases which have come under his observation in England, that it is difficult to determine the interval of time between exposure to the gas and the onset of

symptoms, because there is no way of detecting the presence of the gas. The odor like that of garlic, which has been attributed to arsin, has never been noticed by any of the workmen exposed to it, although it is very easy to detect the arsenious acid in smelter fumes by the garlicky odor. Legge believes that several hours always intervene before the first symptoms manifest themselves. In one case, where frothing of the contents of the vessel was assumed to show the escape of the gas, the man working over the vessel became affected after six hours. There is a great difference in the susceptibility of men exposed to the poison, as shown by two who were working together, one of whom became very dangerously ill and the other of whom escaped with no symptoms. In all Legge's cases the attack began with abdominal pain, vomiting and diarrhea; followed, after an interval of 18 to 24 hours, by jaundice and the passage of dark colored urine containing blood pigments. Six men who later died were ill from 4 to 6 days, and all had suppression of the urine before death.

The experience related by the chemist, Kunz-Krause (41), shows a free period of nine hours before the first indisposition was noted. He had opened an old cupboard containing chemicals and noticed a strong garlicky odor; but from that time, 11 in the morning till 8 that night, he felt perfectly well. Then he began to suffer from nausea and abdominal pain, which increased rapidly; and by midnight he had severe dyspnea and a thready pulse. The symptoms gradually subsided and passed off during the following day. A container of arsenic had leaked and the action of molds had formed arsin or diethylarsin.

Wignall (27) has reported some interesting cases of subacute poisoning by minute quantities of AsH_3 such as may be encountered in the manufacture of dye intermediates. The symptoms were so vague that the diagnosis was made largely on the presence of arsenic in the urine, quantitative tests for which were made by Dôlèpine of the Manchester Public Health Laboratory. Wignall publishes the records of five such cases. Most of these men did not feel ill enough to stop work, but consulted the doctor because of the presence of blood in the urine. They had no serious symptoms, only a yellowish skin, languor and loss of appetite, rapid feeble pulse, and low blood pressure, below 100 mm., yet the analysis of the urine sometimes showed not only methemoglobin and casts, but a fairly large quantity of arsenic estimated as As_2O_3 .

The slow elimination of arsenic is well seen in these cases, the fall to what is considered an amount within normal limits, namely one one-hundredth of a milligram per 100 cc. of urine, taking from four to eight weeks. Case 3 had on December 5th a urine almost black, with specific gravity 1025, containing albumin and 0.2 mg. of arsenic. It took almost two months for him to recover and for

the arsenic to drop below 0.01 mg. Case 4 had abdominal pain, vomiting, jaundice, and the urine was a deep Burgundy red with a specific gravity of 1025, containing much albumin, methemoglobin and oxyhemoglobin, and with 0.185 mg. of arsenic. This was on January 24th. By February 26th only a trace of arsenic remained.

Hydrogen Arsenid in Industry.—Arsin, AsH_3 , is formed when ever, for technical purposes, nascent hydrogen or a hydrocarbon is produced in the presence of a soluble compound of arsenic. There are many ways in which this can occur in industry. The ordinary lead, zinc, copper, and antimony used in manufacturing often contain arsenic, and the iron obtained from iron pyrites also contains it. Commercial sulphuric acid, made by the chamber process from sulphur obtained by roasting iron pyrites, is often contaminated with arsenic; and if this variety of acid is used to make hydrochloric acid from common salt, the latter also may contain arsenic. Contact sulphuric acid is free from arsenic, but is much more expensive than that made by the chamber process, and of course the chemically pure metals are too expensive for ordinary manufacturing purposes. Moreover, as recently discovered by the U. S. Public Health Service, arsenic has been found in zinc sold as chemically pure. It follows, then, that whenever sulphuric or hydrochloric acid comes in contact with iron, zinc, antimony, or lead, an evolution of AsH_3 fumes may occur; for the conditions of Marsh's test for arsenic will have been brought about if either the acid or the metal contains arsenic.*

Such conditions are very common in industry, but the fact that people are not looking for this poison explains why so few cases have been reported in the literature, especially in that of this country. It is probable that when such an accident does occur the acid fumes are held responsible.

The instances of hydrogen arsenid poisoning reported in the literature show the great variety of circumstances under which such accidents may occur. Making acids from arsenic-bearing compounds, especially extracting the arsenic to make chemically pure acid, has caused accidents of this kind in England. When an iron tank which has held such acid is entered by workmen to clean or to repair it, the residue at the bottom may contain enough acid and metal to give off fatal amounts of hydrogen arsenid. There are cases of this kind in Rambousek's reports and a few years ago I was told of three men in a New Jersey plant who were sent into an acid tank to make repairs after it had been supposedly well washed out; but there was still about a bucketful of residue left at the

* In a widespread epidemic of arsenical poisoning from beer, which occurred in England in 1901, the source was found in the use of impure, arsenic-contaminated, sulphuric acid to convert potato starch to sugar in making the beer. More than 6000 persons were poisoned in this way in Liverpool and 70 died.

bottom, which was enough to poison the three men, two of whom died.

The use of zinc dust and hydrochloric acid to produce hydrogen has been a prolific source of poisoning in two classes of men, chemists and balloon fillers. Thus, out of Rambousek's 39 cases, 11 were filling toy balloons, 3 military balloons, and 13 were chemists. This large proportion of chemists is found also in the English reports, and I believe it is not to be explained on the ground of greater exposure, but because poisoning in a chemist is much more likely to lead to investigation and to be traced to its real source; for the chemist knows what he is working with and what are the possible risks.

Ileffter (40) in 1918 collected from the German literature 116 cases of arsin poisoning, divided as follows: Chemical and metallurgical industries, 64 cases; laboratories, 14; making balloons, 22; making toy balloons, 16. To these Koelsch (35) adds the cases which have occurred since that date; namely, 3 from chemical plants, and 11 from a single metallurgical plant,—making 131 in all. This plant was making vanadium iron, which we call ferro-vanadium, for the steel industry. The ore from southwest Germany, called monthranit, contains 6 per cent vanadium, 30 per cent lead, 9 per cent copper, and 0.3 per cent arsenic. It is leached out with sulphuric acid, and this work had been carried on for three years without accident; but suddenly, in some unknown way, hydrogen arsenid escaped, and 11 out of 15 men employed in the room were poisoned severely, and one man died. No odor of garlic was detected by anyone.

The symptoms came on some hours after the inhalation of the gas, and in lighter form they consisted only of headache and nausea, or sometimes neuralgia and paresthesia. Severer cases were characterized by exhaustion, dizziness, nausea, vomiting, diarrhea, and after a couple of days by jaundice. The urine for several days showed blood and bile coloring matters, and the recovery was slow. The diagnosis of acute gastritis was made at first, and only the number of men affected aroused the suspicion of poisoning,—a suspicion strengthened by the appearance of the urine, which was of a clear dark red color, and contained abundant albumin. An interesting history among these was that of the industrial chemist who was exposed to the fumes for a whole day. The next morning he awoke with a sense of confusion, and pains in the kidney region, he was slightly jaundiced, and twice during the day he lost consciousness. His urine was the color of red wine for a period of eight days, and during the same time there was extreme weakness, especially in the legs, and rheumatoid pains in the arms and fingers. In the fatal case, the autopsy findings were very characteristic: general icterus and icteric staining of all organs and fluids, enlargement

of the liver with slight fatty degeneration, gall-bladder full of thick dark bile, enlargement of the spleen. Microscopic examination of the kidneys showed plugging of the convoluted and straight tubules with hemoglobin and fragments of red corpuscles. The circulating blood had undergone a slight degree of hemolysis.

Bannister (42) tells of a fatal case of hydrogen arsenid poisoning from gas produced during the manufacture of zinc chlorid from zinc ashes, and the skimmings of galvanizing tanks, treated with commercial hydrochloric acid. Gases were known to come off freely, but the men were warned to go away as soon as the mixture was made. One day a workman lingered near the tank and by evening he began to complain of pain in the stomach and of vomiting. Cyanosis and dyspnea developed, then jaundice, semi-delirium, frequent vomiting, anuria, the catheter bringing only a few drops of blood. He died of edema of the lungs after four days of delirium.

Legge (28) describes three cases from a plant making bleaching powder. Here there was a still which had to be cleaned out—cleaning and repairing tanks and stills are the most prolific sources of poisoning from all the volatile compounds. The still held a residue of HCl which was later shown to contain arsenic, and the man who went in used a new iron shovel, and a new iron pail. He was working in this enclosed space where the fumes formed by the action of the acid on the metal could not escape, and he died from the effects. A second man was severely poisoned, and when the matter was investigated, it was found that another man had died in the same way some time previously.

Legge also tells of seven mild cases which developed in connection with dipping iron sheets in an acid bath, or pickling them, preparatory to galvanization. A fatal case came from dipping zinc plates in a solution of arsenic chlorid and iron chlorid, in HCl to make "art metal" or "bronze." Other cases were in establishments using the electrolytic process for recovery of copper. Glaister gives the details of three cases of poisoning from this source, reported by the British factory inspection service for the year 1906. The men attacked were employed in emptying vitriol solution from the depositing tanks in the electrolytic recover of copper. The tanks were supplied with sulphuric acid and copper, and a current of electricity was passed through them, the anode being of lead and the cathode of copper. Oxygen and sulphurous acid were liberated from the positive lead end, and copper was deposited at the negative. No ill effects were ever observed during this part of the process; but when the copper had all been deposited, hydrogen was liberated at the negative pole; and if arsenic was present, hydrogen arsin was formed. It was shown experimentally in the laboratory that this was true.

The men employed in emptying the solution were seized with

dizziness; collapse, followed by jaundice; hemorrhage from the kidneys; and fever. They were incapacitated for periods of six weeks, eight weeks, and thirteen weeks. It is noteworthy that one of them felt quite well on leaving work, but began to sicken during his two-mile walk home. No such cases have been reported from work of this sort in the United States; but I cannot help believing that if cases of industrial disease were investigated with the same care that is given them in England, a similar explanation would be found for the frequent break-down of men employed in the acid room of a large plant which uses the electrolytic method of copper recovery. I visited this plant and convinced myself that there was no danger from nitrous oxid fumes or sulphuric acid fumes; but I had no way of assuring myself of the absence of hydrogen arsenid during certain stages of the process.

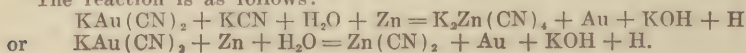
Work in the forming and charging rooms of an electric storage battery plant is seldom productive of any ill-health; but Rambousek tells of a case of arsin poisoning from fumes of AsH_3 in the forming department of a German storage battery works. The lead grids which are immersed in acid, are made of a lead antimonial alloy, and practically no antimony used commercially in the United States is entirely free from arsenic.

Work in a metal pickling shop is notoriously unhealthful. W. Gilman Thompson (33) says "It is generally assumed that the fumes of acids, sulphuric, muriatic, or nitric, are responsible for this," but there is more reason to believe that the cause should be sought in the occasional escape of AsH_3 when the metal or acid or both contain arsenic. Similar processes in photo-engraving may bring about an escape of these fumes.

I know of but one extensive article in American medical literature on industrial poisoning from hydrogen arsenid, and that is the paper by Noble W. Jones (43) of Portland, Oregon, on arsenic poisoning in connection with the MacArthur-Forrest cyanid process for recovering gold and silver. In the MacArthur process dilute potassium cyanid is used to dissolve gold, and the resulting double cyanid of gold and potassium is filtered through a bed of zinc dust, precipitating the gold in fine metallic form and liberating nascent hydrogen, which if the zinc contains arsenic, combines with it and is given off in the form of AsH_3 .*

The cases described by Jones occurred in the Utah mining country. There were five, all severe, and two fatal. They suffered from jaundice, nephritis, hemoglobinuria. The severest cases had deep bronzing of the skin, very dark urine, and sharp paroxysmal pains in the loins radiating down to the thighs. In spite of the extreme

* The reaction is as follows:



solution of hemoglobin as evidenced in the urine, there was no sign of air hunger. The blood showed oligocythemia with a high color index, but the red cells were for the most part normal in appearance. The two men who died had complete suppression of urine before death, and autopsy showed hemorrhagic inflammation of liver and kidneys. The liver was large and clogged with detritus of broken-down cells; the kidneys were swollen; there were sub-cortical hemorrhages; and the tubules were clogged with blood-cell detritus. Jones says that such cases of arsin poisoning were frequent during the first years after the cyanid process was introduced, but they are much rarer now. A case of apparently the same kind was reported to me by Dr. James Arneill of Denver. In this case the man was employed in a cyanid process plant, and suffered from nephritis and profound anemia.

A series of cases, unusual in origin and course, was described just after the war by a British naval officer, Dudley (44). Fifty men formed the crew of a submarine on several of her trips, and among them 30 were sick enough to be sent to the hospital, 15 had symptoms severe enough to keep them on the sick list for a few days, 10 had mild symptoms not incapacitating them, and one escaped. These cases are interesting for several reasons. In the first place, all the men were equally exposed to whatever fumes there were; yet the range of individual susceptibility ran from one man who did not suffer at all to another who had a rapid pulse, vomiting, pain in the abdomen, constipation, headache, tingling of hands and feet, great thirst and burning in the throat, edema of the face, albuminuria, jaundice, and a fall in red cell count to 1,980,000. These cases were slower in onset than is usual, taking two or three days, or even longer to develop. All recovered, though at the last report, some six weeks after the acute poisoning, the blood count was still not up to normal.

The gas in the submarine came from the storage batteries which were found to have been made with a lead-antimony alloy containing 0.2 per cent arsenic. It was not till the grids were well corroded that the gas began to be evolved. The acid used in charging was found to be arsenic-free.

An earlier instance of this same form of poisoning, from much the same source, was described by Giordano (31) of the Italian Navy in 1916, and his report was translated and published in the U. S. Naval Medical Bulletin in the following year. There were three submarines on which, after submerging for periods of from ten to sixteen hours, the crew were found to be suffering from a form of intoxication which was at first attributed to pressure and temperature; but the true nature of the illness was discovered through the fact that on one of the boats there were two separate compartments, one containing the storage batteries with 17 men,

the other with 9 men; and these 9 men felt no ill effects from the submerging, while all of the 17 were ill. In this, and in the two other submarines, the arsenic had collected in the asbestos bags in which the lead plates had been suspended to prevent the crystals of lead oxid (which form especially on the positive plates) from falling down to the bottom as the boat oscillated. In all three submarines the batteries had been newly charged. The varying susceptibility of individuals was seen here also; for among the 17 men in one boat the first case developed nine hours after submerging, the second after 12 hours, four after 14 hours, and the rest after coming up to the surface.

As has already been said, the use of arsenic in making coal-tar dyes has long since been abandoned; but there are two processes in dye making which may be attended by an accidental formation of arsin gas. They are acid reduction, and alkaline reduction followed by neutralization by means of an acid.

Nitrobenzene is reduced to anilin by nascent hydrogen formed from iron filings and hydrochloric acid. By the same method nitrotoluene is made to yield the two toluidins, ortho and para. Hydrogen arsenid may form, if arsenic is present as an impurity in either the acid or the iron. This accident is carefully guarded against in German factories and more or less in the British where accidents have been frequent enough to arouse the factory inspectors to this danger. Reduction reactions are always carried on in closed apparatus and so long as everything goes well there is no reason why fumes of any kind should escape, but if anything gets out of order the reducers must be opened and the so-called sludge cleaned out in order to allow repairing. Five mild cases of arsenical poisoning occurred in a British dye-works from this source, but they were not recognized by anything peculiar in the symptoms, only because an alert physician examined the urines for arsenic. I have been in American dye-works in which the reduction apparatus was so faulty in construction that at least one reducer was always out of order and in process of being cleaned out. The men in charge realized that the laborers who were sent in to shovel out the wet sludge would probably become sick; but they assumed that anilin with traces of unreduced nitrobenzene were the only poisons present. There has never been any attempt in America to discover how far arsin fumes are responsible for sickness in the manufacture of dye intermediates.

Alkaline reduction is distinctly more dangerous in British and German dye works, but not in American, than acid. Nitrobenzene subjected to alkaline reduction yields benzidin; nitrotoluene yields toluidin; and these are very important intermediates. The process is as follows: Nitrobenzene is reduced with zinc dust and sodium hydrate through successive stages to hydrazobenzene which forms colorless crystals. Now, in our larger dye-works, these crystals are

simply filtered out and the zinc dust in the filtrate is used over again. This is a perfectly safe procedure. But in the British factories, and so far as I know in the German and in our smaller factories, they add hydrochloric acid to form the soluble zinc chlorid and get rid of the zinc in that way. The temperature must be kept down, for in the presence of warmth some benzidin would form and be lost in the filtrate. In England the cooling is done in a very crude way, by dropping in a chunk of ice, and in the summer of 1918 five cases of severe arsin poisoning occurred in a dye works among the men who were near enough to the tank to be reached by the fumes which escaped when the ice was thrown in. When I was there a year later they had arranged a long sluiceway for the ice, so that the man could stand far enough away from the tank to ensure his safety. The only American plant that I know of which is now using this method has a much safer way of lowering the temperature, —by brine coils, instead of by ice. In the German dye works I was told that every source of fumes, no matter of what character, was treated as dangerous because of the possible formation of AsH_3 or H_2S .

An illustration of this form of poisoning was furnished by a small plant in New Jersey which made naphthionic acid from alphanaphthylamin and sulphuric acid; and also benzidin base and sulphate by an alkaline reduction process involving contact between hydrochloric acid and zinc dust. The construction of the plant was crude, and fumes from the different processes were allowed to escape into the room. One night five men were at work in the benzidin department, and when the acid was added at the end of reduction there was a "boil over," and the fumes affected all of the men. Their subsequent history was obtained partly by personal interview with one of them and partly from the records of the hospital to which two others were sent.

The first man, C, had been employed in the plant for eighteen months, and had often suffered from the fumes in the benzidin department. On this night, he went home feeling so ill that he could not even get into bed, but dropped down on the floor. He did not send for a doctor, thinking it no worse than former attacks, until he saw that his urine was the color of blood, when he became alarmed, for this had never happened before. He was ill for about three months, suffering from pains in the kidney region, a band-like feeling around the lower part of his abdomen, intense pain in the back of his head and neck, vomiting, poor appetite, depression, and loss of strength. During this time his wife said that he looked like "a yellow corpse." When seen about eighteen months later he still had pains in the kidneys, headache and buzzing in the head, and his strength had not returned.

The second man, D, was treated at home for about two weeks for

supposed typhoid fever, and no details as to this part of his history can be obtained; but probably, judging from the diagnosis, he had symptoms of abdominal distress of an aggravated kind. When he was finally brought to the hospital the Widal test disposed of the typhoid fever theory. He was then, on the fifteenth day after the accident, in a semiconscious condition; there were ulcers on lips, throat, and tongue; he had diarrhea and vomiting; and his body was shaken with tremors of the muscles. Albumin was found in the urine, but no blood. There was a very marked anemia, the red blood corpuscles being reduced to 1,780,000. Both spleen and liver were enlarged. In spite of his partial delirium he evidenced great pain and difficulty on urination, and this symptom increased, together with diarrhea and frequent vomiting, during the two days in the hospital. Toward the end there was complete anuria. He died on the third day, but no autopsy was made.

E went to the hospital 48 hours after the accident. He was then jaundiced, complaining of great pain in the lower chest and over the bladder, vomiting greenish fluid, voiding blood-red urine. There was also pain and difficulty in urination. These symptoms persisted for two days, then slowly improved, and he was discharged on the sixth day, "cured" according to the hospital record, but according to C he had not recovered his health eighteen months later, nor had he been able to do a full day's work. No blood count was made in this case, but hemoglobin was found in the urine.

As for the other two, one never reported back to the plant, and C knew nothing of his history. The fifth, a cousin of C, recovered completely.

The diagnosis of anilin or alphanaphthylamin poisoning was made in the hospital, as was to be expected. In such cases, poisoning by the benzene derivatives must always be considered, but the diagnosis should not be very difficult when the symptoms reach such a degree of severity. The jaundice of anilin or nitrobenzene poisoning is very slight, the urinary changes slighter than in arsin poisoning and much more transient. On the other hand cyanosis is marked. The symptoms do not increase progressively, but usually disappear in a few days, the urine assuming a normal color and the anemia improving rapidly. No case is on record of a typhoid condition resulting from poisoning by the amido compounds of benzene, and if death occurs, it is within a short time after the accident.

Wignall's (27) five cases, already described, were employed in reduction processes, four in making benzidin, the fifth amido-diphenylamin. Their symptoms and the color of their urine might easily have been interpreted as mild anilin poisoning. Undoubtedly there must have been many instances of this mild arsenical poisoning among workers in reduction processes, which have never been detected because there was nothing about them to arouse suspicion.

The fact that arsin gas colors mercuric chlorid yellow makes it possible to detect small quantities in the air by suspending above the suspected tank a piece of filter paper wet with mercuric chlorid.

Wholesale poisoning by the fumes of arseniuretted hydrogen, not strictly industrial in origin, has been reported several times, the victims being always people confined in ill-ventilated parts of a ship, carrying in the hold a cargo of an alloy of iron and silicon, ferrosilicon (Glaister (45)). This is a very important compound used in the manufacture of electrodes and in the production of steel. It is made by fusing together in an electric furnace, silicon (in the form of sand and quartz), coke, and iron. Arsenic and phosphorus may be present in the quartz or the iron, and in the presence of the coke they are converted into calcium arsenid and phosphid which in moist air may be partly changed to arseniuretted hydrogen and phosphoretted hydrogen.* According to Pellew (46) nine tons of ferrosilicon is capable of giving off in 24 hours 110 cubic feet of poisonous gases, consisting of AsH_3 , PH_3 , C_2H_2 , and H_2S . This is true if the material is dry; but if it is moist the amount of gas may be trebled. This decomposition occurs most readily in products containing 30 per cent to 70 per cent silicon, grades above and below this being affected much less seriously.

Formerly we imported our ferrosilicon from Germany, but of late years we have made it at Niagara Falls. The only instance of poisoning of this kind that can by any stretch be called American is that which occurred in 1905 on the *Vaderland* bound from Antwerp to New York with a cargo of ferrosilicon. Fifty steerage passengers came down with a mysterious sickness from which eleven died, and the vessel was detained at quarantine under the suspicion of plague; but the discovery of the nature of the cargo explained the real cause. In 1907 five more deaths occurred on another vessel from the same cause, and in 1909 another five. It must be borne in mind that the gas which arises from the ferrosilicon may be mixed, containing PH_3 as well as AsH_3 . Since we are now manufacturing ferro-silicon, storing and transporting it, we must bear in mind the possible hazard connected with it.

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CHAPTER 17

MERCURY

MERCURY vaporizes even at the temperature at which water freezes. Renk (1) analyzed the air above half a square meter of surface covered with mercury, and found that two centimeters above it, a cubic meter of air contained 1.86 mg; at half a meter above it the amount was 1.26 mg.; and at one meter, 0.85 mg.; averaging 1.5 mg. per cubic meter of air. These experiments were made at 10° C., or 50° F. Renk calculates that a workman, breathing about 4 cubic meters of air during eight hours' work, would ingest 6 mg. of mercury.

The quantity of mercury in the air which is sufficient to set up slow chronic poisoning was determined by Göthlin (2) of Upsala University, who was involuntarily the subject of a human experiment. For some reason, which cannot be ascertained from the abstract of his paper, there was in the physiological laboratory where he worked, more or less mercury spilled on the wooden floor. He developed a marked case of chronic mercurialism with mercury in the urine, and also found mercury in the urine of other men working in the room. His conclusions are: (1) the inhalation of mercury for months or years in quantities up to 0.4 to 1.0 mg. in twenty-four hours is capable of producing in a healthy person a pronounced type of chronic mercurialism; (2) if the mercury is not over 1 mg. pro 4 cb. m. it will be practically all resorbed; (3) neither in scientific nor in industrial establishments should mercury be handled in rooms whose flooring is made of permeable material.

Cole, Gericke, and Sollman (3), working on the use of mercurial inhalations in the treatment of syphilis, have found that the inhalation of from 10 to 40 mg. will cause bronchial irritation and slight salivation; in some cases profuse salivation and soreness of the gums which bleed easily. Their usual method was to give 5 mg. on the first day, 10 mg. on the second, 20 mg. on the third, 40 mg. on the fourth, then after an interval of three days, a daily dose of 20, 40, 60, 80 mg. for four days. Salivation developed usually during the first course of treatment and was increased during the second. They believe that mercury is not absorbed through the lungs, but condenses on the mucous membranes of the mouth and pharynx and respiratory tract. Mercury was found in the mouths of ten out of twenty men who were examined by Giglioli (4) in an Italian mercury reduction works.

That mercury may be absorbed through the unbroken skin is well known, but in industry this is much less important than the absorption of vapors through the respiratory tract. Cole, Gericke, and Sollman give several instances from early medical literature of poisoning from mercurial fumes. In 1810 the British ship, *Triumph*, had some mercury containers broken in its hold. As a result, all the birds and cattle on board died; 200 sailors had symptoms of mercury poisoning, and three of them died. In 1804 there was a fire in one of the quicksilver mines in Idria, Austria, and a good deal of mercury vapor escaped into the air and spread over the countryside. They quote Hermann (*Wien. med. Wchnschr*, 1850, No. 40) as follows: "Nearly all the townspeople showed effects of mercury, though in slighter degree than the miners, by contact with those whose clothing was impregnated with mercury and giving off mercury vapor in the air. Even the animals, for instance cows that pastured near the furnaces or in their lee, were affected. The cows became salivated, cachectic and aborted, or the calves born at term died early. Nine hundred persons in the neighborhood had mercury tremor." Another instance is found in two barometer makers who slept in a room with a pot of quicksilver on the stove. One of them was only slightly salivated but the other was made tremulous for life. Two cases of poisoning were traced to poorly silvered mirrors made by the old process of backing with quicksilver which was insufficiently coated.

It is important to remember that mercury-soiled clothing may be the cause of poisoning; for the continual vaporization of the mercury will result in the breathing of tiny quantities even when the man is not at work. Some years ago when work was carried on in certain California mines where the ore contains metallic quicksilver, there were miners' wives who became poisoned as a result of washing their husbands' overalls.

Mercury is believed to circulate in the blood in combination with sodium chlorid as an albuminate (5). It has been recovered from the liver, kidney, spleen, intestines, bone-marrow, and testicles, remaining longest in the liver and the bones. Elimination is very slow and it may be several months before the body is quite free. All glands, salivary, intestinal, gastric, and sweat glands, as well as the liver and kidneys, aid in excretion, and the irritating effect upon these tissues produces some of the symptoms characteristic of mercurialism, as for instance the salivation from irritation of the glands of the mouth, and the increased production of bile with the appearance of bile coloring matter in the urine from irritation of the liver. Giglioli found urobilin in 14 out of 20 cases of pronounced mercurialism.

In severe cases there may be ulcers in the large intestine (Koelsch (6)), and also changes in the liver shown by increased

blood sugar and glycosuria. Degeneration of kidney epithelium and eventual cirrhosis of the kidney have also been described as a result of chronic mercurialism. Mercury has been isolated in the urine repeatedly and the amount estimated quantitatively (see Buchtola (7)), but according to Teleky (8) the elimination is intermittent and the test may be negative in serious cases. There is a direct effect on the central nervous system, the pathogenesis of which is somewhat obscure, although lesions of the motor nerve cells and degeneration of the myelin sheaths have been produced experimentally in animals.*

Most authorities (Lehmann (10), Teleky (8), Koelsch (6)) distinguish between the typical slow chronic form of industrial mercurialism and a subacute form which develops comparatively rapidly as a result of exposure to relatively large doses. For the latter Kussmaul's (9) classical description, published in 1861, still remains the most vivid and detailed picture in the literature. His observations were made among the Nuremberg-Furth mirror makers in the days when the method of backing mirrors with quicksilver was still used. Cases of such severity are now comparatively rare, but they are still found occasionally; for instance, in mining native quicksilver; in roasting ore in poorly constructed furnaces; in recovering the metal from condensers; in making thermometers in badly ventilated shops; in making and using mercurial solder. (See Devoto (20).)

Giglioli's investigations of mercurialism in the reduction works of Monte Amiata, Italy, brought to light cases of this kind quite as severe as Kussmaul's. According to Lehmann there was a good deal of severe, subacute mercurialism in Thüringen when thermometer making was a home industry. During the war, between January 1917 and May 1918, Koelsch observed 116 cases of severe mercurialism in a war industry which apparently involved the use of mercury and mercuric oxid in the making of some chemical.

Mouth.—In this form of mercurialism, inflammation of the mouth and salivation are usually prominent and early symptoms. In some of Koelsch's cases pain on chewing began as early as the second or third day of employment. Many men notice first a queer taste in the mouth, some say it is metallic, others sweetish. The teeth feel queer and unnatural as well as painful. There is a sensation of heat in the mouth; and sometimes, but not always, there is an in-

* Letulle, quoted by Kobert, p. 338, produced localized paralyses of peripheral nerves by administering mercury inhalations. The myelin sheaths were degenerated. E. Leyden (*Deut. med. Wchnschr.*, 1893, n. r. 31, p. 733) describes polyn neuritis mercurialis and so does Heller (*Wien. kl. Wchnschr.*, 1896, n. r. 9, p. 153). Raymond and Sicard found lymphocytes in the spinal fluid and isolated mercury from it, and Brauer was able to produce in rabbits lesions of the motor nerve cells by injections of mercury. (See Guillain, G. and Laroche, G. (19).)

creased flow of saliva. In Koelsch's cases, inflammation of the gums began around the wisdom teeth and extended to the lining of the cheeks, more marked on that side on which the patient usually lay at night. The gums look bluish and swollen, they bleed readily. It is not easy to distinguish an early mercurial gingivitis from the pyorrhea of neglected mouths, such as is often seen in the poorer class of laborers, but the latter is confined to the margin of the gums, does not spread, and is not accompanied by salivation.

The odor of the breath is said to be recognizable by experienced men who call it "metallic," in serious cases it is fetid. The tongue is described by Tylecote (11) as large, dove-colored or silvery, flabby, and as showing indentations from the teeth. Kussmaul described as a sign of chronic mercurial stomatitis a coppery red color of the throat, palate, and pharyngeal ring. Koelsch found this in the early stage only, not associated with any other symptom. Usually the mouth lesions yield to treatment in two or three weeks, but they may be very obstinate, progressing even while under treatment. Various descriptions are given of the mercurial line which is occasionally observed along the margin of the teeth. According to Monti (12), it simulates quite closely the Burtonian lead line, but is more brownish; while Adler (13) calls it bluish; Glibert (14) a dirty red, rarely blue; and Tylecote describes it not as granular, but as an almost uniform purplish line along the swollen margin of the gums. Among 468 hatters-furriers workers Glibert saw a typical Burtonian line with bluish patches on the mucosa of the cheeks in 57, or 12.8 per cent.*

In severe cases of this subacute type the inflammation of the mouth may be great enough to make speaking and eating impossible. A California mechanic who had a five or six days' job replacing fire bricks in an ore furnace had a mouth so swollen that his lips stuck out, he could not speak or chew, and it was painful for him even to swallow liquids. His breath was extremely fetid, but ptyalism was not marked. The degree of ptyalism varies very much. Koelsch has seen as much as five liters of saliva formed in twenty-four hours, but in some cases of subacute mercurialism this symptom is slight or quite lacking. Thus, Giglioli who found stomatitis in seventeen out of twenty mild cases, in sixteen out of forty-four severer cases, and in eleven out of twenty cases of incapacitating mercurialism, says that ptyalism is not a marked feature of chronic mercurial poisoning. In the California quicksilver reduction works I found that the name universally used for mercurial poisoning was "salivation"; but that in the majority of cases, even of severe poisoning, there was little if any abnormal flow of saliva.

The slower form of mercurialism, the typical chronic form, is the one that has been prevalent in the hatters' trade for many years;

* Nach Wright found a bluish line in three out of 100 hatters.

in the metallurgy of mercury where this is done by modern methods; and in all the mercury-using industries in which the exposure is slight; although even there a subacute form may develop in an unusually susceptible person, for susceptibility to the poison varies greatly in different individuals and even in experimental animals. Perhaps the most typical cases of slow chronic mercurialism are seen in felt hat-makers and hatters-furriers, trades in which men remain for many years and where they are repeatedly exposed to very slight amounts of mercury in vapor form.

In hatters there is often little or no salivation. Monti thinks that dryness of the mouth is usual, with perhaps an occasional attack of salivation. Teleky says that mercurialism in hatters is characterized by tremor without salivation, and Glibert also believes that an excessive secretion of saliva is unusual in this trade. It is true that there was profuse salivation in all the five severe cases described by Adler, but so rapidly developing and extreme a form of intoxication as he described is exceptional in this trade. An interesting contribution to the literature on this feature of mercurialism is made by Giglioli who found mercury in the mouths of 32 mercury smelters with pronounced forms of poisoning.

Tremor.—Mercurial tremor is seldom the first symptom of subacute mercurialism, for even if there is no stomatitis there are usually nervous symptoms, such as sleeplessness and irritability, before the tremor appears.* In slow, chronic poisoning such as occurs in hatters, it may be the very first symptom noted, as it is certainly the most characteristic. It comes on gradually, the patient noticing first difficulty in writing, in putting his spoon in his mouth, in lacing his shoes, in lighting a cigarette. It is a fine trembling of the muscles which, characteristically, is interrupted every few minutes by coarse shaking movements (Giglioli, Teleky). When the hands are stretched out with fingers spread, the tremor is seen distinctly; then it diminishes as the man becomes accustomed to the position, and it may die away for a minute, only to start up again. Tylecote says the fineness of the tremor has been overstated; it is coarser than that of exophthalmic goitre or of alcoholism. Taylor's (15) tracings showed eight per second. It is not so regular as the tremor of alcoholism (Teleky) or of paralysis agitans, and according to Erben (16) there is another distinction between paralysis agitans and mercurial tremor; namely, that in the latter the whole hand trembles, while in paralysis agitans each finger has its own movement. It begins usually in the fingers, but in the early stages can often be seen in the eyelids when the eyes are closed, in the lips when they are drawn back to expose the teeth, and in the protruded tongue. It is an intention tremor, increasing as efforts

* Giglioli says that painful cramps in the muscles of legs and arms, especially at night, almost always precede tremor.

are made to control it, and increasing with precision of movement. For instance, if a glass of water is put into the outstretched hand the tremor increases and it increases still more if an attempt is made to carry the glass to the mouth. The tremor tends to die down if the man is at rest and feels himself unobserved, in which it differs from senile palsy; and it stops during sleep, even in extreme cases. There are usually no sensory symptoms accompanying it, although there may be some numbness and profuse sweating of the palms.

As the case progresses the tremor passes to the arms, and then to the legs which may jerk and jump, especially when the leg is swung forward in walking. Going up and down stairs becomes especially difficult, and a lad whose case is described in the report of the Civic Federation (7) could get downstairs only by sitting down and lowering himself from step to step. It is very difficult to walk a narrow path, especially if there are whirling belts on either side or moving machinery, for the effort to avoid them makes the man sway to that side. In several instances described to me a workman who was still capable of carrying on his trade, the motions of which had become almost automatic, was not able to reach his bench alone, but had to be guided there by a fellow workman. In Orange, New Jersey, there was a famous case of "hatter's shakes" in a man who kept on at work long after he had developed severe tremors. He could not feed or dress himself, and the only way he could get to work was by pushing a baby carriage before himself to steady his gait. When he reached the plant he was guided to his bench and then he could carry on the work familiar to him through years of practice.

W. Gilman Thompson (18) saw a case of generalized tremor as severe as paralysis agitans: and Adler (13) in 1891 described five cases of mercurialism in hatters, with palsy far severer and more generalized than is often seen at present. One of these was a man of 35 who had been a hatter for ten years, had lost flesh from year to year, and had suffered from frequent attacks of indigestion and constipation. At the end of eight years tremors began. They were in the hands at first; then they spread all over the body and were accompanied by muscular twitchings, but there was no impairment of sensation. The tongue was affected and the speech was hardly intelligible. There was marked blurring of the vision. The man suffered from terrifying dreams and had much difficulty in walking, especially in going downstairs.

Kussmaul (9) has described tremors so extreme that not one muscle of the body seems to escape, and clonic spasms so severe that the combined strength of several strong men is not sufficient to control the jerking which throws the patient to and fro and threatens to hurl him out of bed. Among Giglioli's cases a number had clonic spasms which were painful and very exhausting. They are likely

to come on during sleep, appearing earlier than the tremor and sometimes lasting after it has disappeared under treatment. In other cases the spasms come on during work, last from ten to thirty minutes, completely incapacitating the man. The Italians call them "la stirarella" from the word meaning to pull violently. They affect not only the limbs but the head. Tonic spasm is rarer, but Giglioli saw it in five cases involving usually the arms, but sometimes the shoulders or legs. He calls the condition toxic tetanus. It can be brought on sometimes for a few minutes by pressure on a nerve trunk. For instance, pressing on Erb's point may produce tetanic contractions of the shoulder.

Dr. F. S. Ryan of San Jose, California, gave me the history of a remarkable case of this sort, and later I had an opportunity to meet the man and to hear his story and that of his fellow-workmen. He is a Spaniard, employed first as a miner and then as furnace man, and he was evidently unusually susceptible; for he had several attacks of poisoning while mining cinnabar where the danger is very slight. An attack would begin with a queer sweetish taste in the mouth, followed by colicky pains and diarrhea; but there was never any inflammation of the mouth or salivation, nor has there been loss of a tooth. The most serious symptom was tremor. From the mines the patient went to work in a reduction plant and was put on a Scott furnace where the fumes were very bad. During this time his tremor was practically constant and very troublesome, especially if he were excited, making it sometimes impossible for him to feed himself. He drank a good deal of native California wine but not whiskey. In spite of the doctor's warning, he continued at work on the furnaces; and then one afternoon at about three o'clock, in his home in the mining camp, he suddenly began to have violent clonic spasms of the right leg which, as he described it, "began to work up and down like a pile driver." The thigh would be drawn up on the abdomen, the leg flexed against the thigh, and then violently extended again, and all the efforts of his fellow workmen failed to hold it still. According to Dr. Ryan, who saw him about three hours later, the right leg was jerking back and forth rhythmically about 60 times per minute without any variation and with great violence. Morphin had no effect on the spasm, although it induced drowsiness. There was no change in his condition under treatment by purging, by applying hot packs, and by putting ice to the head; nor could he be made to sleep even with morphin. The next morning a supinator spasm of the right arm developed, synchronous with that of the leg. Chloroform was then tried, but the spasms did not stop till the stage of surgical anesthesia was reached and began again before consciousness was regained. There was no cerebral symptom except the insomnia. Thirty-six hours after the onset sleep was obtained under chloral, and the

spasms diminished in violence. Under the continual administration of chloral and purgatives and sweating the spasms gradually died down, but did not cease entirely till the seventh day. The exhaustion was extreme, especially as the patient could only take liquid food and only a very little at a time; for he could not keep still long enough to swallow much. He was discharged from the hospital emaciated and weak, and for a year after that he could not work, but was a prey to headache, insomnia, bad dreams, depression or irritability. Nevertheless, he went back to the furnaces the following year and worked for six or eight months till his increasing tremor finally compelled him to give it up. I saw him at the works where he was employed as a teamster, and he told me he had never recovered his former health. He is always nervous, irritable, and easily upset, a statement which was heartily endorsed by the bystanders. Just recently he had had an operation for gastric ulcers, and under the excitement of preparing for it his tremor returned for several days.

Mercurial tremor usually passes away if the patient can be induced to give up his work before it has reached a serious stage, but in every hatting center there are stories told of men who have had the "shakes" for years after quitting the shop, as, for instance, of a man in Danbury, Connecticut, who had typical tremors for thirty years after he gave up the hatting trade. It is the universal testimony of hatters and of mercury miners and furnace men that alcoholism greatly favors the development of mercurial tremor. Indeed, some say that no total abstainer ever has a very severe case of the shakes.

In France there has been a controversy over the nature of the mercurial tremors (see 19). Charcot held that there was no pathological change in the nervous system and that the tremor was hysterical—the men being influenced by mimicry, by expecting the tremor, dreading it, brooding over it, and so becoming nervous and emotional. The same theory was held by Lereboullet and Lagave who call mercurial tremor "psycho-névrosique." Guillain and Laroche (19) dissent emphatically and hold that the tremor is toxic in origin and depends on lesions of the cerebellum or the cerebellar tracts. They emphasize the cerebellar characteristics; *i.e.*, an uncontrollable intention tremor with scanning speech and some ataxia of hands and fingers. They insist that the tremor is very difficult to simulate: that in fact the men try to control it; that it is typical and could not be reproduced exactly at will by all the workmen affected. It cannot be cured by psychotherapy, but is cured by removal from work, although they saw two men, in one of whom it persisted for thirty years and in the other for forty-two years.

Alteration of speech is often noted, but Giglioli says it is not

typically scanning: it is hesitating, thick, or stuttering. The handwriting resembles that of paralysis agitans, but is characteristically most abnormal at the start and at the finish; just as in all action the greatest difficulty occurs in beginning and in stopping, especially if the orders are given quickly. The reflexes are always exaggerated. Ankle clonus is said not to occur, but Giglioli elicited it in twelve furnace men. The electric reactions are normal.

Psychoses.—Kussmaul's erythismus mercurialis takes several different forms and is characteristic of both subacute and chronic poisoning. It is usually a late symptom, but Devoto (20) reported three cases of subacute mercurialism originating in a dry battery plant, in all of which the first manifestation was a very slight stomatitis followed by marked physical weakness, mental depression, headache, and dizziness.

Giglioli noted psychic disturbances in 15 severe cases. Loss of memory was the commonest complaint, often associated with torpor from which if the patient were aroused, he showed great anxiety or irritability. Excitability or shyness were also noted. These men were not neurasthenic,—they had no tendency to exaggerate their symptoms; on the contrary, they were timid and diffident. In one very severe case there was delirium with hallucinations, intense tremor, clonic spasms, followed by paresis, mental torpor, and loss of memory. Paresis was noted in two other cases, but Giglioli interprets it as the pseudo-paresis of exhaustion described by Oppenheim in chorea.

The hatters' trade with its long-continued exposure to minute quantities of mercury vapor yields very typical instances of erythism. Harris (21), who investigated this trade in New York City, says that men he stopped to watch as he went through the factory would sometimes throw down their tools and turn on him in anger saying they could not work if he looked at them. The hatters interviewed by Wright (22) described themselves as easily upset, easily angered or embarrassed, especially if spoken to quickly; while others were timid, full of vague fears. A man in Danbury told me of his brother, a hatter, who died at 28 years after suffering for some time with severe tremors. He was depressed and melancholy and "at times his mind would drift."

Among the mercury miners and metallurgists in California this symptom of mercurialism is very familiar and the men recognize it in themselves as well as in others. They describe an increasing shyness, anxiety, embarrassment at being noticed, loss of self-confidence, or irritability which is very marked if the man is spoken to suddenly or asked to do something unusual. Some men are obliged to give up work because they can no longer take orders without losing their tempers; or, if they are foremen, they have no patience with the men under them. Sometimes insomnia is the chief com-

plaint, or bad dreams, or depression and loss of memory. Other men become drowsy and fall asleep as soon as they sit down. A young man who was one of a small group of quicksilver producers in California had a severe attack of mercurial stomatitis during which he lost most of his teeth; and he became apathetic and drowsy to such an extent that at a meeting of the company at which the most crucial questions involving the fate of the business had to be decided, he fell asleep in his chair. The most serious forms of mercurial psychosis reported in American literature are found in the histories of cases of mercurialism in New York City and vicinity which were collected by the National Civic Federation (17). Despondency, loss of memory, melancholia with suicidal tendency, even manic-depressive insanity, was discovered by these investigators in the records of some cases.

Blood.—There is nothing characteristic in the blood. The red cells are likely to be moderately diminished, and there is a slightly greater loss of hemoglobin; but stippled cells are not found. Devoto reports two cases in which he found a polycythemia with a very low color index. Giglioli's red counts ran from 2,800,000 to about 4,800,000; but there were only three with the lowest count. He found in 7 specimens from his severer cases nucleated reds, and in 21 there was poikilocytosis. No significant change was found in the white cells by Giglioli. According to Agasse-Lafont and Heim (23) there is a lymphocytosis, sometimes so great that the formula is reversed; but this sign appears too late to help in the diagnosis: rather it is of grave prognosis. There is nothing to distinguish the blood of early mercurial poisoning, and if any striking changes are found they indicate profound impregnation with mercury.

Among the 108 felt hatters and hatters-furriers examined by Wright, 39 had a systolic blood pressure exceeding the age plus 110, the average excess being 14.4 mm. Hg. The average pulse pressure was 56.4.

Skin.—Mercurial eczema is mentioned by several authorities, and Koelsch connects it with the excretion of mercury by sweat glands. I have never myself seen an instance of it either among hatters or hatters-furriers or miners or metallurgists.

Gastro-intestinal.—Subacute mercurialism may take a gastro-intestinal form, with colic, diarrhea, less often constipation. The colicky pains may be very severe and the discharges may be bloody. I have the record of a physician, specializing in genito-urinary work, who in the absence of a rubber regularly employed by him was obliged to give mercurial rubbings and used his bare hands. Not long after he began this he had three violent attacks of abdominal pain closely resembling lead colic. He could find no possible source of lead poisoning, and the attacks ceased after the rubbings were

discontinued. Several histories of severe colic with bloody diarrhea were told me in the California quicksilver region.

No characteristic symptoms are found in the gastro-intestinal tract in chronic cases. Tylecote says diarrhea is unusual in hatters, and Adler did not find it once in his five severe cases. Constipation is much more common. Monti says that Italian hatters acquire a distaste for red wine, and Schoull found among French hatters a curious change in appetite,—a distaste for meat and a craving for vegetables, spices, and acids.

Urine.—There is difference of opinion with regard to urinary findings. Koelsch found in his chemical workers albuminuria, polyuria, or oliguria; and evidence of epithelial necrosis or of cirrhosis of the kidney. Monti says that polyuria is common in hatters, while Tylecote says that scanty urine occurs too often among these workers to be accidental. Both say that albuminuria is rare. The kidney may eliminate mercury for a long period without albumin appearing in the urine; for mercury has not nearly so damaging an effect on kidney or blood vessels as lead. On the other hand, both Teleky and Harris have found albuminuria in a large number of cases of mercurialism in hatters. Wright found albumin in 5 out of 21 specimens from hatters, all of whom had a systolic blood pressure exceeding their age plus 110. Giglioli found abundant urobilin as the most frequent abnormality in the urine. In a group of 20 men with marked mercurialism he found it 14 times, and in 30 specimens from men with mercurial cachexia not employed at the time, he found it in 11. Bile pigments were present in three of these and albumin in five.

The cachexia of mercurialism is rarely seen nowadays. It is described by Koelsch who saw nine cases among his 116, by Giglioli who found 20 such among 130 Italian miners and furnace men, and by Monti who studied mercurialism in Italian hatters. There were also instances quite striking among the Civic Federation cases. The skin is pale or sallow and dry, there is loss of hair, emaciation, the hands and feet are cold, there is indigestion, and the nervous and psychic symptoms are very marked.

Giglioli found certain symptoms which are not mentioned in most descriptions of chronic mercurialism. These are: punctate hemorrhages under the skin, present in 14 cases; nosebleed, mentioned in 9 histories; enlargement of the liver, found in 14; loss of sense of smell in 9 out of the 20 severest cases.

Another result of chronic mercurialism which is rarely seen is "ostitis mercurialis decalcificans" and mercurial necrosis of the jawbone. According to Kobert (5) (pp. 332 and 333), there is first inflammation of bone marrow and periosteum, especially of the lower jaw; also a solution of the bone salts through formation of lactic acid (Sabbatini). Necrosis of the jaw follows suppuration

of the teeth and resembles phosphorus necrosis, leading to the formation of sequestrs. The otitis of mercurialism is a subject of controversy; for it is usually attributed to syphilis,—but Kobert thinks that the decalcifying effect of mercury has been proven by the experiments of Prévost, Eternod, and Frutiger. Kobert also says that in 1087 Constantius Africanus described mollities ossium in mercurialism.

Fatal cases of industrial mercurialism are certainly very rare, although Lehmann says that some deaths have occurred from it. Eichhorst (24) described a case of fatal septicemia from staphylococcus aureus infection which found its way through the mouth in the course of a severe stomatitis. The man was an electrical machinist working in a room with mercury scattered over the floor.

Mercury in Industry.—Quicksilver has been mined in Almaden, Spain, since Roman times, and we know that mercurialism was recognized even then; for Pliny, the Elder, in writing of the diseases of slaves mentions mercurialism, plumbism, and the consumption of potters and grinders. For many centuries work in the Spanish mines had to be carried on by slaves, and then by convicts; and when free labor was introduced it was found necessary to limit the hours of work, because there was so much incapacitating illness among the men. Therefore a tradition grew up which is still in force, that eight days of four and a half hours each, thirty-four hours in all, should constitute a month's work. The metallurgical processes in use at the present day in Almaden are very antiquated and little is done for the prevention of mercurialism among the 2100 miners and the 400 furnace men, aside from the shortening of the day. (See De Kalb (25).) These mines have, in addition to the cinnabar ore, a considerable deposit of native quicksilver, which adds greatly to the danger of mining, as Lehmann (10) noted when he visited them. Spain is the oldest of the quicksilver producing countries and still leads the world in production.

Italy now takes second place; for she has not only the mines at Monte Amiata in Tuscany, but as a result of the Treaty of St. Germain, Italy has obtained possession of the very important Austrian deposits and metallurgical works at Idria in the upper Isonzo. Quicksilver has been mined here for more than four centuries, and the first description we have of the symptoms of chronic mercurialism was written during the first half of the 16th century by Andrea Mattioli of Siena who had observed it among the miners of Idria. Some two hundred years later, in 1761, Giovanni Scopoli of Alto Isonzo wrote a remarkably clear description of mercurial tremor in Idria miners. (See Monti (12).) There is said to be still some free quicksilver in these mines, but the metallurgical technique has greatly improved of late; and there are no longer

any severe cases of mercurialism among miners or furnace men, few that are even moderately severe, but many that are mild. The system of alternation of work, shifting the men periodically after one month of furnace work to two months of outside work and back again, has been in force since 1897 in Idria, and as a result the cases of mercurialism fell from 122 in 1898 to five in 1908. (See Lehmann (10).) In addition to this precautionary measure the men have a six-hour day. The institution of this short working day in April, 1665, in what was then the province of Friuli is said to be the first legislative measure of industrial hygiene known to history. (Pope, quoted by Lehmann.)

Much less favorable are conditions in the Italian mines at Monte Amiata. Mercurialism has been notorious here ever since the first half of the sixteenth century when, under the influence of Paracelsus, mercury came into great demand for medicinal use, and the roasting of cinnabar ore was undertaken. Up to that time production had consisted simply in washing free quicksilver from powdered ore. Conditions seem to have been very bad up to the middle of the nineteenth century, and though after that, metallurgical processes gradually improved they also became complicated, required more oversight, and if neglected or entrusted to unskilled workers resulted in an excessive contamination of the air. (Giglioli (4).) The furnaces now are of the Cermak-Spirek type; the ore drops down a series of inclined planes, growing hotter as it goes down, the gases rising and passing to condensers where the mercury and soot and other impurities collect on the sides and bottom. The free droplets of the mercury run out through pipes; the rest is entangled in the soot which is shoveled out, mixed with lime, and put through an Exeli press to be squeezed out. There is exposure to fumes and contact during these processes; and, according to Giglioli, when he visited the works in 1909, hardly any man could work on furnaces or condensers for as long as one year without becoming poisoned.

In 1920 the United States held third place in the world production of quicksilver, by far the greater part of the metal coming from California, with Texas following long after. There was, of course, a striking decline in production after the war; for the greatest demand for quicksilver comes from the manufacturers of explosives. Fulminate of mercury, a constituent of all percussion caps and "booster charges," is the most important industrial compound of mercury. The other uses for this metal are: metallic mercury for thermometers, barometers, and, to a lessening extent, for vacuum pumps, especially in X-ray apparatus; for solder in dry battery manufacture; for the production of amalgam in gold and silver extraction; for dentists' use; and for the method of gold-plating known as fire gilding. Mercury is also needed for the production of

the acid nitrate used in the preparation of fur for felting and for the production of various pharmaceutical compounds.

In spite of the importance of quicksilver mining in the United States, little has been known about actual conditions in the industry or the occurrence of mercurialism among quicksilver miners. The only statement in the literature is a quotation by Kober (26) from the Eleventh U. S. Census report to the effect that among the miners of New Almaden, California, about 10.44 per cent suffer from mercurialism. It seemed impossible to trace this statement to its source or to supplement it in any way; and in order to ascertain the actual facts at present in this field, I visited, in the summer of 1923, the two largest quicksilver mines in California—the New Almaden and the New Idria with their reduction plants, which in both places are situated near the mines; for it is much cheaper to transport the flasks of mercury than the quantities of ore, and the reduction processes are simple. The New Almaden has been mined since 1850; the New Idria is much more recent.

The California quicksilver mines are not deep, few running down as much as 500 feet below the outcrops. Ninety-five per cent of the ore is cinnabar, HgS , with meta-cinnabarite, a black amorphous variety of the sulphid. There are also mines in California where native quicksilver is found in the serpentine area. During the war the latter in which, as the men say, "the silver runs free," were worked because of the great demand for quicksilver to make fulminate; but the temperature sometimes runs as high as 90 degrees or over, volatilizing the mercury, and salivation and mercurial tremor developed to such a degree that the mines had to close down for lack of labor. Drilling for the charge produced a fine dust, laden with tiny droplets of mercury, and the quicksilver released by blasting would coalesce into large drops which ran down and collected under the rock and dust and had to be scooped up. Even working the men in two-hour shifts with two hours off, providing hot sulphur baths, and urging them not to exert themselves too much, was not enough to prevent sore mouth, ulcerated gums, pytalism, tremor, nervousness, irritability, depression, insomnia or drowsiness, which developed with great rapidity among the miners. None of these mines, rich as they are, are worked at present.

The metallurgy of cinnabar reduction is very simple; for it is decomposed at as low a temperature as 338° to 420° C. (Hofman) into metallic mercury and SO_2 . The methods have been much improved of late and there is no longer an escape of vapors laden with mercury as there was from the earlier type of furnace. No sampling or assaying is done. The ore is sorted by hand; is crushed, screened, dried; and either roasted in a Herreshoff furnace, automatically fed and mechanically rabbled, or in revolving kilns. It is roasted with abundant air supply to oxidize the sulphur, and

since HgS dissociates at 400°C ., the roasting of HgS results in the production of the metal, not the oxid. A draft of air carries the mercury vapor, dust and carbonaceous "soot" or "stupp" to condensers, a Cottrell precipitator being introduced to get rid of the dust if the latter is excessive. Condensation takes place in pipes or chambers which may be of iron if dry; but if a cooling spray of water is used sulphuric acid will be formed from the SO_2 and the condenser must be of tiles or wood. Quicksilver is said to penetrate all these substances, working its way through the lining of the furnace, iron pipes, fire brick, terra cotta, and, of course, impregnating the sides of a wooden condenser so that every now and then it must be torn down and put through the furnace. At the time of my visit to New Almaden they were recovering mercury from the ground thirty feet under an old furnace, cradling and washing out the dirt as in placer mining.

The condensers are cleaned out, sometimes by flushing with a hose, sometimes by shoveling; and the mud or sludge thus obtained, together with the dust from the Cottrell precipitators, is mixed with lime; dried; and either sent back to the furnace or treated first on steam tables, the mixture being raked back and forth till droplets of quicksilver collect and flow down to the quicksilver kettle. After this treatment the residue is heated in a retort and the last traces of mercury removed.

Volatilized mercury is encountered in the furnace work, in cleaning out the condensers, especially by hand, in the work at the steam tables, and in charging, raking, and discharging the retorts. The dust from the furnaces is partly composed of quicksilver "flour," which means a suspension of mercury in very fine subdivision.

The men in the California field are all familiar with the symptoms of mercurialism and most of them have at some time suffered from at least one attack of what they call "salivation," although it is plain that they use that term to cover mercurial poisoning of any form whether or not there is any increased secretion of saliva. The most rapid and severe cases seem to occur in work on the old type of furnace, on the Scott furnace, on the retorts, in mining native quicksilver, in working up the dirt under old furnaces, or in the ruins of a fire. In such cases the mouth and lips become very much swollen, the man can hardly speak, and can take only liquid food; the teeth become loose; there may be ulcers in the mouth, a very fetid breath; and there is usually, but not always, salivation. Colic and diarrhea, sometimes bloody, come on in these cases, and then a marked mercurial tremor appears which lasts weeks or months. In the more slowly developing cases, which are seen in the reduction plant under modern conditions, the lesions in the mouth are much milder and may not be present at all, while tremor is the most conspicuous symptom. Some men with marked tremor

told me that they had never had more than a metallic or disagreeably sweet taste in the mouth and a slight inflammation of the gums. Others had had only tremor and headache, insomnia, irritability.

There is a general agreement among the men that any alcoholic drink, even native California wine, increases the tremor and psychological symptoms. These latter consist in a change of disposition, increasing unreasonableness, "crankiness," resentment of orders or advice, increasing sensitiveness, readiness to take offense, excitability with insomnia or depression, continual drowsiness, and a tendency to fall asleep no matter what the man is doing.

The men have also very definite ideas as to the proper way to prevent poisoning. They believe that the habit, so prevalent among the Spanish miners, of rolling their own cigarettes is dangerous because it requires only a little over 300° C. to reduce cinnabar and produce mercury vapors, and they believe that this occurs when cinnabar dust is mixed with the tobacco or smeared on the cigarette paper and the cigarette is then lighted and smoked. This danger is even greater if the man is handling pure quicksilver. Old hands always advise the new men to give up smoking and begin chewing tobacco instead, believing, as most workers in dusts and poisons do, that constant spitting gets rid of much of the inhaled poison. They believe also that if a man takes a shower-bath, rinses his mouth, and puts on fresh clothing, not his working clothes, at the end of his shift he can protect himself against an attack. For treatment they advise getting out of the fumes and working hard, to "sweat the poison out."

Mercury is not used as much in industry as formerly; for what used to be one of the most important mercury industries, the making of mirrors, now requires only silver nitrate. Teleky (8) says that fire gilding, that is, applying gold-mercury amalgam to a baser metal and then driving off the mercury by heat, is, in Austria, productive of more poisoning than any other industrial process in which mercury is used. There is very little of it nowadays in the United States. It is said that objects which must be exposed to the weather, such as church crosses and ornaments and the buttons on naval uniforms, are still fire gilded, but electro-plating has displaced it for all other work. Three of the cases in the Civic Federation report came from this source. The mercury amalgam method of extracting gold and silver from rich ores is still used, but as the rich ores become exhausted the MacArthur-Forrest cyanid process comes into use more and more.

Another formerly important use for mercury is gradually being abandoned; namely, the use of mercury pumps to exhaust the air in incandescent lamp globes to produce the necessary vacuum. These pumps often broke and the mercury was scattered about. Foreign literature on industrial mercurialism has a great deal about the

incandescent lamp industry and the risk to the workers. In this country such pumps are no longer used, except in X-ray apparatus.*

In 1918 Legge (27) summarized the facts concerning 208 cases of mercurial poisoning which were reported to the British Home Office between May, 1899, when this form of occupational poisoning first became notifiable, and December, 1918. The distribution was as follows: Fulminate, 54 cases; thermometers, 45; hatters-furriers, 27; electric meters (with bath of mercury), 24; felt hat industry, 19; chemical works, 19; water gilding, 12; lining sweet molds, 4; mercury lamps, 3; bronzing, 3; card dressing, 3; photo-engraving, 2; other, 2.

Teleky says that even under the best hygienic conditions one must expect one or two cases of mercurialism to develop among 100 workers; and according to Kobert (5) (p. 332) miners, even in the best mines, have from one to two per cent mercurialism, and the smelters at least eight per cent, sometimes of a very severe form.

Metallic mercury is used largely in making thermometers and barometers, and although we have no accurate data on the incidence of mercurialism in this occupation, yet evidently conditions in the inferior shops favor it. Thermometers are made from rounded strips of glass with a central bore. The strips are cut to the required length, one end is heated to melting in a gas flame, and a bulb is blown in it by means of an air pump. Mercury is heated over a Bunsen flame to make it very fluid, and is filled in; the top of the stem is sealed, and the head rounded off; and then the tube is sent to the engraving department where it is dipped in paraffin, then in wood alcohol, and etched in hydrofluoric acid. The acid is washed off with water and the tubes are laid in kerosene oil to remove the paraffin.

Over the places where the bulbs are being filled it is customary to place hoods, but unless there is an excellent exhaust connected with the hood its only effect is to hold down the vapors rising from the heated mercury and prevent their diffusing through the room. Every now and then the bulb of a thermometer breaks and spills over the work benches and the floor. As these are of wood, little droplets lodge in cracks and crevices and are not swept up. Such a room is usually hot because of the many gas flames and the steam from the heated water which is used for testing the thermometers. The objection made to better ventilation is usually that if the windows were open, or if there were a strong suction applied near the work benches, it would deflect the flame of the burners and hinder the work. Sometimes the heat applied to the reservoir of mercury is no higher than is absolutely necessary, but in other cases no care is

* A similar danger is found in what is known as the "constant potential" departments of electrical works, when an alternating current is changed to direct by passage through a large flask of mercury.

taken to keep down the temperature. In two factories investigated in New York City by Jacobsohn (28), it was found that no washing facilities were provided beyond cold water and that the street clothes of the workers were hung in the shop, absorbing the vapors. Lunch was eaten in this same room. Teleky calls attention to another danger in thermometer manufacture; namely, lead poisoning from the use of lead colors in marking.

Solder for dry batteries contains mercury and the making and use of this solder is productive of a form of mercurialism which is likely to be unusually acute; for the heat used in melting and soldering volatilizes the mercury rapidly. I have the history of a man employed in a small battery plant where he melted up old battery plates which had been soldered with or which had been made of mercury-zinc amalgam. At the end of two weeks he complained of headache, feverishness at night, pain in all his teeth, pain on attempting to open his mouth, pain on swallowing. There was a tender swelling in the neck under the jaw, his tonsils were enlarged and cryptic, his tongue was coated, gums were swollen and tender, there were pus pockets near many teeth, and there was some pus discharging from a recent extraction cavity. His temperature was 99.3 and his pulse 105. There was no lead line and no abnormality in the urine. Devoto's cases, already mentioned, came from this industry.

Mercury amalgam is still used for extracting gold and silver from the richer ores. The method consists in crushing and screening the ore, then running it over a cold copper plate which has been coated with mercury, and the latter forms an amalgam with the gold. This is scraped off with a rubber scraper and made into balls in water by squeezing with the hand in a cloth. It is then retorted, and the mercury distilled off is recovered in water and used again. The ore so treated still contains gold and is subsequently put through the cyanid process. A Californian who was for twenty years in gold mining and recovery, using the amalgam method, told me that he saw only one case of salivation and that was in a prospector who retorted the amalgam in an open retort and let the mercury vaporize, not caring to save it.

The occurrence of chronic mercurialism among dentists as a result of continual handling of amalgam has caused a good deal of speculation and Blomquist (see Schulte) claimed to have found in the urine of dentists as much mercury as would be found after a therapeutic inunction. More recently Schulte (29) published a careful study in this field. He used a slight modification of Buchtala's method for the quantitative estimation of mercury in the urine and found it present in all of the 18 examined, but in quantities too small for intoxication. Those studied were dentists and dentists' assistants using amalgam continually in their work. The quantities found in twenty-four hour specimens were as follows:

	Cases
Trace of mercury.....	2
0.045 to 0.065 mg.....	11
0.075 mg.	1
0.11 mg.	2
0.14 mg.	1
0.16 mg.	1
	<hr/>
	18

He concludes that the mercury is absorbed by breathing the vapor, and not through the skin; because the result was the same whether or not the individual came in direct contact with the amalgam. Thus a dentist who never touched it had a little more mercury in the urine than his assistant who worked it up. Two men who had only a trace in the urine worked with amalgam but in large, well ventilated rooms and only for a few hours. None of these persons showed any sign of mercurial poisoning, but a recent article by Meiné (30) describes a case of marked mercurial dermatosis in a dental assistant. This young woman, who had been engaged in clearing up amalgam fillings, presented herself with edematous swelling of the eyelids, blurred vision, photophobia, lachrymation. There were blebs on eyelids and conjunctiva, also on the back of the ears; and there was a shotty erythema along the side of the neck. She had a slight watering of the mouth and the parotid was tender. Meiné reports it as an instance of idiosyncrasy to mercury.

The most important compound of mercury is the fulminate, which is produced as follows: mercury is treated with nitric acid to form mercuric nitrate and this is then poured over alcohol in large glass flasks or "balloons." Immediately there is an evolution of thick vapors, white changing to red, and when they subside the inner surface of the balloon is seen to be covered with fine crystals of fulminate of mercury which are carefully washed out. The exact composition of these vapors is not known; but one constituent is ethyl nitrite, and during the war I heard of many instances of the physiological effect of this well known drug on workmen, especially on hot, still days.

In the Annual Report of the Chief Inspector of Factories and Workshops for 1918, Legge says that the figures for mercurial poisoning showed an increase in 1916 and 1917, caused by the greatly increased use of fulminate of mercury, but only a few of the cases showed the recognized symptoms of mercurial absorption, salivation, tremor and "nervousness." The great majority were cases of dermatitis or eczematous ulceration of the face, neck, hands and forearms, associated with conjunctivitis and inflammation of the nasal and laryngeal mucous membrane. The reports showed that in many

instances the condition followed exposure of not more than two or three weeks.

In the United States this form of poisoning was very troublesome, causing an excessive labor turnover in detonator manufacture. The only figures available, however, were collected during 1916, before our entrance into the war (31). In one plant employing both men and women there were 32 cases of dermatitis among 1070 women and 36 among 505 men. The difference between the sexes was attributed to the greater effort made by the women to avoid a disfiguring eruption. The condition was described as a moist eczema, the skin reddened, swollen and tense, later exuding serum, then sealing. The eyelids were often much swollen. Hands and forearms were affected first, then the face, neck, genitals. No note was made of any of the usual symptoms of mercurialism in these cases, but in Austria Oppenheim (32) reported in 1915 a number of instances of that kind. Among 13 persons suffering from mercurial dermatitis he found 8 with mercurial stomatitis, swelling of the gums, bleeding, salivation.

The next most important compound of mercury is the acid nitrate, made by treating mercury with nitric acid, and used for the preparation of fur for felting, the process known as carrotting. This industry is described in a separate chapter. Finally, mercury is used in the making of several pharmaceutical preparations, one of which, the bichlorid, is a constituent of anti-fouling paints for ship bottoms.*

* According to recent reports of factory inspectors mercurial poisoning has occurred in Bavaria in the production of acetic acid from acetylene by the use of large quantities of mercury or oxid of mercury as catalyzer.

CHAPTER 18

THE HATTERS' TRADE

The Trade of the Hatters-Furriers and of Felt Hat Manufacture.

—The making of felt is centuries old. Oriental shepherds were supposed to have discovered accidentally the felting property of wool when subjected to heat and moisture and gentle pressure. It was known to the Greeks. Pliny says that the Gauls made a felt so strong that it would resist a sword stroke, especially if vinegar was used in making it. Saxon writers mention "fellen haets." According to the legend, St. Clement the Roman, patron of the hatters, once on a pilgrimage lined his sandals with wool to ease his feet and found that the heat and sweat and pressure had formed a sandal of felt. For long ages the primitive method of making felt hats persisted and it may be seen even now in Russia. Fur, cut from the skin by hand and blown up into the air by the vibrations produced by striking a bowstring, fell over a cone-shaped form and was covered and pressed with a wet cloth. These processes now are carried on by machines, almost all of American invention, and to a certain extent, the subsequent processes of shrinking and hardening the felt and shaping and smoothing the hat are carried on by machine, although hand work still persists in some of the most modern factories where it is held that no machine can take the place of the trained hand of the sizer or blocker or pouncer.

The features that have given to the felt hat industry its reputation as one of the worst of the "dangerous trades" are the presence of great quantities of fine fur in the air of workshops, and the use of acid nitrate of mercury as an aid in the felting of fur. The fine hairs which form the fur of rabbits' skin and of the skin of hares, muskrats, beavers, etc., are smooth, resilient, and straight. Treatment with some chemical which makes them limp, twisted, and rough, greatly aids in the felting process, and many chemicals have been shown to produce such an effect. Among them is the acid nitrate of mercury now used in the preparation of hatters' fur in all countries except Russia. This method has rooted itself deeply in the industry during more than two centuries. It has been traced back to the middle of the seventeenth century when it was a secret in the hands of a few French workmen, evidently Huguenots; for at the revocation of the Edict of Nantes in 1685 when the Huguenots fled to England, they carried the secret with them, established

the trade there, and for almost a century thereafter the French were dependent on England for their felt. In France the fluid was called and is still called *le secret*, the process *secrétage*, the workers *secréteurs*; but in English-speaking lands the words carrot, carrotting, and carrotters are used, because when white skins are thus treated and heat-dried they take on a carrot color. The formula used is still more or less a secret, although probably the proportions of mercury and nitric acid do not vary much. The French formulæ, some of which are used also in this country, are said to call for the addition of white arsenic, As_2O_3 , and of mercuric chlorid. Arsenic has also been found in the water of a sizing kettle in England. The trade is classed as dangerous above the average in European countries and bears an especially bad reputation in France, Belgium, and Russia. According to Legge (33), mercurialism in hatters' furriers was first described by Reitz of St. Petersburg in 1829.

The industry is divided into three parts, although all three may be carried on in one plant, and two very commonly are. The first is fur cutting, which includes the preparation of raw skins for carrotting (treatment with nitrate of mercury); drying; brushing; cutting fur from pelt; sorting the different grades of cut fur, packing them in paper bags; blowing raw and carrotted fur. This branch is unorganized and is manned very largely by foreigners. It does not require an expensive equipment and many of the fur cutting shops are small and very cheaply built and managed. Sometimes fur cutting includes reclaiming waste fur of all kinds and waste felt from hat factories.

The second branch is hat making or "back shop" or "wet work" which begins with blowing, and includes forming, hardening, sizing, and the multitude of processes for shrinking and shaping the felt. It may also include what is called preliminary pouncing; that is, rubbing off hairs with fine sandpaper.

The third branch is hat finishing or "front shop" or "dry work" which includes dry blocking, shaping, final pouncing, crown and brim ironing, and also stitching, banding, trimming, etc.

It would be unfair to make any general statement about this industry in the United States without qualifying it, for there are always at least a few shining exceptions to every indictment one is forced to bring against the industry as a whole. While fur cutting plants are usually poorly built, crowded, dark, ill-ventilated, and almost incredibly dusty, there are several which are well-constructed and well-managed and which compare favorably in almost every respect with the best in Europe. This is especially true of a large factory in Philadelphia where all the branches are carried on under the same roof, and of two in Brooklyn, and of one in Danbury. Standards on the whole are lower in Connecticut

than in New York and not quite so high in New York as in New Jersey.

Hat making requires a much larger outlay of capital than fur cutting and the factories are better constructed and employ a higher class of labor. Much more ingenuity has been expended in the effort to do away with the sources of danger and discomfort in this branch; yet the difficulties are great and often they have not been surmounted. It is very common to find the blowing room thick with dust flying through the air and lodging on every surface; the forming and sizing departments full of steam, the floors awash, water dripping from the ceiling. Hat finishing is on the whole less troublesome than hat making, and conditions in the trimming rooms are usually good, often excellent; but the pressing and pouncing departments are among the most dangerous in the industry, and here the safeguards may be very inadequate.

In comparing American with European plants one finds that the advantages are not all on one side. French fur cutting has some features better than those in Danbury, but at least one which is worse—the drying of carrotted fur in heated rooms which must be entered by the workmen. English hat manufacture is superior to the best American in one department only—the forming room. The factories that I visited in Italy and in Czecho-Slovakia (though more especially in Italy), were vast in construction, with more than ample space, so that any air-contaminating substance is greatly diluted, and during the great heat of July, 1921, I suffered less discomfort in these factories than I had in Danbury in April and May. Cool air was driven into the heated rooms with so strong a draft that it blew one's clothing about. The windows on the sunny sides were covered, either with heavy linen curtains or with Venetian blinds. Steam from boiling kettles and tanks was removed more efficiently than in the great majority of American plants; and the work in the forming rooms was dry and easy, while in American plants it is wet and heavy. The drainage of floors in American plants always leaves something, usually a great deal, to be desired. In the Borsalino factory in Alessandria the cement floors in the wet rooms are stamped in squares with deep lines so that the feet will catch and not slip, and this permits a much steeper slope to the floor than is possible with smooth cement.

The care of the individual workman has never been a responsibility of the employer in this industry in the United States. It is customary to provide long rubber gloves for the carrotters, but other working clothes, as well as soap and towels, must be provided by the workman. In France, Germany, Great Britain, and Czecho-Slovakia all men and women who handle fur after it has been carrotted must be furnished full suits of working clothes, including caps; and in Italy, although the law does not require it, I found

the same thing in the Borsalino factory and in De Valera and Ricci's near Milan. Medical inspection of all those exposed to mercury is required in these countries with the exception of Italy. It does not seem to be provided in any American plant.

The description of felt hat manufacture given here is not technical; it deals with various processes only so far as that is necessary in order to demonstrate the unhealthful features if there are any. For a thorough expert report on the technical problems of ventilation, steam, fume and dust prevention or removal, lighting, etc., the reader is referred to the very complete report compiled by Miss Lilian Erskine for the New Jersey Department of Labor and published in 1915 under the title "Sanitary Standards for the Felt Hatting Industry." Models of exhausts, hoods, etc., may be seen in the State Museum of Safety in Jersey City.

Raw Skins.—The handling of raw fur is filthy work, the odor is very disagreeable, and rarely is any effort made to lessen the unpleasantness. The skins are in sleeve form as they come from the trappers who pull them off the carcasses as one pulls off a glove. The skins are first dampened, then they are cut open, cleaned with knives, stretched, cleaned in tumblers with sawdust or carded with a wire brush, and then the long stiff hairs must be removed; for these will not felt. Hand plucking or pulling is considered by far the best way to get rid of these hairs, and this is done on a large scale in Belgium; and Belgian hand plucked skins are sold to the trade all over the world. In America, machine plucking is sometimes used, but the common method of ridding the skin of hairs is to put it through a shearing machine to cut off as much hair as possible without injuring the fine fur. The shearing may be very dusty, and it seems to be generally assumed that this fur dust is dangerous, but the findings of Wright (22) do not bear this out. Nevertheless, employees have the right to protest against the choking air and thick dust which covers every surface in many plants. It is common to find all the men chewing tobacco to encourage the flow of saliva so that they can spit out the fur they inhale.

Carrotting.—Treatment with mercuric nitrate, or carrotting, comes next, and may be done by hand or by machine. The hand worker dips a stiff brush into the solution and scrubs it vigorously into the fur side of the skin. The machine operator passes a raw skin under a revolving brush which dips down into the carrot and then runs over the fur. There does not seem to be much difference between the two processes unless it be that the hand carrotter is more exposed to fumes. His advantage, however, is not great; for, although the machine for carrotting is covered, there is a fine spray from the brush. The machine operator carrots 5000 to 6000 skins a day and the hand carrotter only about 2000. The men protect their hands with rubber gloves, their forearms usually with stocking

legs, and they often wear a pad of felt or wool over the chest and abdomen.

Carrotting fluids differ in different countries and in different factories in the same country. Yellow carrot always has more nitric acid, white more mercury. The carrot used in New Jersey, according to Miss Erskine, is mercury 20-30 pounds, nitric acid 100 pounds, diluted with 20 times its volume of water. Stetson's procedure is as follows: 19.69 per cent mercury, 31.79 per cent nitric acid (58 Bé). This, diluted to 13 Bé results in: mercury 4.28 per cent and nitric acid 6.89 per cent, which is the strength used in carrotting.

Drying.—It is at this stage that the greater part of the mercury in the skins passes off by vaporization. Heaps of freshly carrotted skins are carried on men's shoulders to be dried, yellow carrot with heat; white carrot, at ordinary temperature. Americans use about 80 per cent of yellow carrotted furs and 20 per cent of white, the European procedure being just the reverse. For yellow carrot, the usual way is to dry the skins in great "stoves," which are closed chambers with steel walls containing a series of heated shelves, and in some factories each shelf has its own narrow opening, closed with a metal flap. The skins are spread on long trays, then pushed in on the shelves, and after an hour or so drawn out through the narrow opening. This is a good arrangement; nevertheless, the great tray of hot skins when it is drawn out gives off mercurial fumes which are breathed not only by the men who tend the stoves but by the carrotters as well; for the stoves are often in the carrotting room. A decidedly worse method is to place the skins on racks and to provide the stoves with wide doors through which the racks may be pushed in and pulled out. The best arrangement of all is rarely seen outside New Jersey. It is essentially an endless wire apron passing slowly along over steam pipes with a narrow opening for a feed door, an automatic discharge, and an in-draft to prevent the escape of fumes.

White carrot is sometimes dried over the stoves, but usually in a separate room at ordinary temperature, the skins being hung or spread about a large room which sometimes opens into a working room. There seem to be different theories with regard to white carrot. In one plant air is driven into the room by fans, whereas in another no ventilation is allowed; for it is held that the skins must dry in still air.

Storing.—Before storing the dried skins must be dampened, and this work is often done by women. All who handle the carrotted skins show deep yellow stains on the hands, and it is inevitable that they should inhale volatilized mercury. The storage rooms in which the skins are stacked for varying periods to "ripen," sometimes for many months, are often in the basement of the building and poorly

ventilated. The work of the storage-room man, filling and discharging the great wooden slatted bins, is regarded as undesirable even by the most optimistic employer, and analyses made by Anne Minot (34) of skins before and after storing showed that a decided loss of mercury had taken place. (See page 268.) Storage rooms should be quite shut off from workrooms, but I have seen them opening,—and the doors open at the time,—into the fur-mixing room, into the brushing room; and in one case storage room and carrotting room were the same. Since wood absorbs mercury the New Jersey Department of Labor advises against its employment in the construction of storage rooms.

Brushing.—Brushing the carrotted skins is usually done by machine. Obviously from this time on, dust is a much more serious item than it is in the raw skin department; for it is now laden with mercury. The woman brusher usually works at a bench with a pile of carrotted skins lying on an iron shelf under which is the brush. She holds the skin against two rolls which catch it, carry it over, brush it, and bring it back again to be pulled out. These women have yellow stains on their hands. The dust may be carried off by exhausts if the brush is so arranged that it revolves away from the brusher, and this is sometimes true; but when, as in some factories, it runs toward the brusher the exhaust cannot catch all the dust and a fine fluff can be seen on the face of the brusher, especially on the chin.

Cutting.—The cutting machines are an American invention, very efficient and horribly noisy. This is by far the most trying part of a hat factory to the outsider; for the din made by the machines is almost intolerable. The cutter, almost invariably a man, feeds the skin into the machine which, by means of stationary and rotary knives, shreds away the pelt and delivers the fur on a flat tray. Women sorters, sitting at a long table in front of the cutter, receive this tray. Their task is to remove bits of skin and tangled fur ("dags"), and then to sort the fur into different grades,—the cheeks and feet forming the inferior, the center of the back the superior grade (except in the case of water animals whose best fur is on the center of the belly). From three to five sorters work with each cutter. This is what is called in England "locking."

The shredded pelt, which looks like excelsior and is known to the trade as "noodles," is gathered up from the floor, and if there is a good deal of fur clinging to it, it is shaken violently, a dusty procedure which should not be allowed and which is not necessary, because a well set cutting machine will deliver very clean noodles. The final destination of the shredded pelt is a glue factory.

The fluff in the cutting room is seldom abundant, but is very fine, and can sometimes be seen on the women's hair or on the caps they usually wear to protect their hair. Work in the cutting room is

not considered as bad as in subsequent departments where steam is a prominent feature, and this impression is doubtless justified since the mercury volatilizes less in the absence of heat. The women sorters weigh the cut fur and pack it in paper bags which go to the storage room for cut fur (another notorious source of mercury fumes), which is usually very poorly ventilated.

In fur cutting factories several processes are carried on which are excessively dusty but not dangerous. Thus "blown fur" is produced by pasting scraps of raw fur on paper and putting it through a cutter. Trimmings from fur coat factories are chopped and blown. "Roundings" cut from the edge of felt hats are bleached and chopped and blown.

Mixing.—The fur from the cutting shop is mixed sometimes by hand, oftener by machine, and then goes to the "devil"; i.e., a cone-shaped box with a fan bringing in a draft of air to blow the fur, and teeth which revolve and pick apart the fur, so that the draft can catch it and mix the different varieties together.

Blowing.—This is almost always an excessively dusty process in American plants. Indeed I have seen but four plants which were fairly dust-free. The blower is essentially a series of compartments, usually six, enclosed in fine wire netting and furnished with a traveling apron which feeds in the fur and rapidly revolving pickers which catch it, pick it apart, and toss it in the current of air formed by their revolutions, letting the heavier hairs and the dust fall to a space between the apron and picker. The air, of course, passes out through the netting and the amount of fur carried out depends on the rapidity of the revolution of the pickers and also somewhat on the quality of the fur, for if a great deal of short fur and "roundings," i.e., ground up felt trimmings, form part of the mixture, more will escape during the process of blowing. The fur tends to cake or felt over the inner surface of the netting and must be shaken down by beating on the outside, a procedure which is sometimes done by machine, sometimes by hand. The fur also cakes inside the machine and the work of cleaning is very dusty. Moisture is necessary to keep the fur from clinging together in masses and this is commonly provided by jets of steam driven into the room through pipes placed at intervals. The combination of steam and choking dust make the usual American blowing room a trying place. I have seen fur flying about as thickly as a heavy snow storm, and in one Danbury plant the steam and fur had formed a solid felt coating over the windows. In a Brooklyn plant the dust from the machines was increased by the use of compressed air to blow the accumulation of fur off the top of the apparatus. In such places the faces, hair, and clothing of the men are covered with fluff, and they chew tobacco constantly because the expectoration helps to get rid of the fur in the throat.

The great Stetson plant in Philadelphia has an excellent blowing room. The draft within the blowers is as strong as in other plants, but a heavy oilcloth hood with the glazed surface inside curving over the blowers prevents dust from escaping. Another excellent feature, which I have seen nowhere else except in the Mutual Fur Cutting factory in Danbury, is the delivery of steam into the machine instead of into the room, which means that far less steam is needed and the air in the room is not too unpleasantly humid. In both these factories mechanical beaters flap continually against the network to dislodge the dust.

European blowing rooms are far less dusty, they are freer from fluff than the best American, and yet the blowers are not covered. The dustiness seems to be a question of the rate of revolution of the pickers; the more rapidly they revolve, the greater the air current and the greater the escape of dust. Certainly the blowing rooms in the English, Italian, and Czecho-Slovakian factories I visited formed a strong contrast to the usual American departments, although none had so good a humidification system as our best plants have. In one of the Italian factories, Valera and Ricci at Monza, no humidification at all is used; they do not find it necessary in that warm climate. The New Jersey Department of Labor believes that humidifying is greatly overdone in American factories, that it is quite unnecessary in warm weather, and that the usual 65 per cent to 75 per cent of moisture is needed only in cold weather when the air is full of electricity.

Forming.—The ingenious machines used in every country for forming are of American invention. Blown fur is weighed by girls into quantities sufficient each for one hat. The girls stand at the back of the former (the machine is known as the former, the operator as the coner) and a traveling belt carries the weighed fur to a great cylinder where it meets first a picker which picks it apart, and then jets of steam which warm and moisten it, then a strong current of air which catches it and sucks it down over a perforated brass cone placed on a turn-table in a chamber at the end of the cylinder. This process forms an even, loosely compacted layer of felt over the brass cone about three times as large as is desired. The coner opens this chamber—and a puff of dust always escapes as he does so—throws a burlap wrung out of boiling water over the cone and its delicate fur covering, fits a similar cone over it, lifts them off, and plunges them into a tub of boiling water which stands beside the former.* This gives the fur cone its first shrinking, and it can then be lifted off, wrapped in burlap, and given to the hardener who slips it over hand and arm or spreads it on a bench, examines it for flaws, “stops” the weak places with fur, and picks out dags.

* Coners are sometimes divided into coners and “wetters.”

The hardener then puts about a dozen cones together, sprinkles them, kneads them with his hands for the first hardening, and sends them to the sizing room where the 30 to 35 inch cone is gradually shrunk down ("sized") to about one-third and changed from loose delicate felt to a hard, even structure.

The work of the coner is very hot and heavy, and the pace is practically incessant. The air, even in the best ventilated rooms, is full of steam and the floor is streaming with water. Analysis of the air from the formers has shown the presence of mercury; for the steam volatilizes it, and to this air are exposed not only the coners but hardeners and girls employed in weighing batches.

Forming is less strenuous and far less disagreeable in Europe. The reason is that the hot water needed to give the cone of delicate felt its first shrinking is applied within the former by means of a long jet of water which plays evenly over the surface of the revolving cone just before it is taken out. Then all the workman has to do is to open the former, gently lift off the cone of felt, fold it together for the inspector, and wait for the next one to form. There is no steaming tank, the floor is dry, there are no heavy brass cones to lift repeatedly, and the work is light and leisurely compared to the same work over here. This method was used in all the foreign plants I visited and was common in this country some twenty years ago. Another good feature was the vast size of these rooms in the European plants, providing air enough for the suction in the former.

Sizing Room.—After the inspection of the cone, it goes to the sizing room and there it is put through a series of processes known as hand starting, wetting down, pulling out, sizing, blocking, wringing or whizzing, etc., all of which are essentially the same and consist in the application of boiling water and pressure to shrink the felt down to the proper size and then to shape it. Sizing, whether by machine or hand, is very laborious work, and is carried on in an atmosphere of humidity and heat. The hand sizers (sizers may also be called "makers") usually work in groups of eight at an octagonal "battery," that is, a tank of boiling water with a wooden bench running around it. The sizer first sprinkles several hats with boiling water, usually acidulated with a small amount of sulphuric acid, kneads them gently with his hands, then as they harden he works them more vigorously and plunges them into the water, cooling his hands in a pail of cold water. Finally he takes one hat at a time and beats it with a wooden rolling pin. He usually protects his hand partially by a leather or wooden shield over the palm. This is the work that the English call "planking."

Sizing machines are like large clothes wringers, only with wooden rolls obliquely fluted, and the sizer alternately dips a bundle of cones in the tank of boiling water below the rolls and places them between the rolls. The sizing room is full of these boiling kettles, and

it is rare to find one which is not foggy with steam, and with water dripping from the ceiling and running in streams on the floor.

Great efforts have been made in certain factories to control the steam in the sizing room by exhaust ventilation and by control of the temperature; for if the moisture-laden air comes in contact with cold air from open windows it condenses, a thick fog forms, and against a cold ceiling this fog turns to water and rains down on the men's heads. The problem is excessively difficult in our variable American climate and success has been obtained only in those factories in which adequate exhausts are installed at the place where the steam is generated; for once it has been permitted to escape into the air nothing effective can be done to get rid of it. There is general testimony from the workmen as to a decided improvement in sizing rooms during recent years, but conditions in most of the plants outside New Jersey still seem productive of discomfort and fatigue if not of mercurial poisoning.

In a large Philadelphia factory where a great deal of hand sizing is done, the kettles are protected by a circular hood with an exhaust pipe and with a curtain composed of flaps of heavy canvas which hang from the edge of the hood to the edge of the kettle, the sizer pushing the hat under the flap. This arrangement prevents escape of steam. For sizing machines some of the Orange plants have a metal hood with an exhaust pipe enclosing all of the sizing kettle except for an opening in front just large enough to work through. Very much the same kind of hood is used in Borsalino's factory and here an excellent feature is the rough cement floor sloping well to the drains and the efficient control of the temperature by big registers in the floor through which delightfully cool air is sent in summer and warm air in winter.

Stiffening.—The majority of hats made in American factories are of soft felt but require some stiffening. This process is of no importance from our point of view; for the stiffening compound is simply shellac dissolved in hot water, borax, and common salt, rubbed in with a brush and then steamed to melt the shellac and drive it in. For stiff hats (this word is applied only to derbies) the procedure is different. The hats are first shaved by a machine like a small lawn mower which clips off the ends of those hairs that have escaped the blowing process and become incorporated in the felt. The stiffening department is usually quite separate because of fire risk from the vapors of alcohol used to dissolve the shellac. Denatured alcohol is used with varying quantities of wood alcohol according to the formula selected; for the revenue law allows from four per cent to twenty per cent of wood alcohol in the mixture. Up to 1906 straight methyl alcohol was always used for the stiffening; and it was largely through the efforts of the Danbury hatters, backed by the physicians in Danbury, that the law was passed by Congress

providing for revenue-free denatured grain alcohol. This has brought about a vast improvement in the stiffening of felt hats, but it must not be forgotten that denatured alcohol is not free from danger. The addition of so little as two per cent of methyl alcohol has been known to lead to characteristic poisoning (Loewy and von der Heide (35)) and the formulas used for stiff hats usually contain as much as ten per cent of it. It is well known among stiffeners that some men cannot stand the fumes even of the denatured alcohol, although others are not affected at all. Drying these hats may be a source of danger; for mercury has been found in the course of recovering the alcohol.

Dyeing.—Dyeing may be done at several different stages. For mixed colors the blown fur must be dyed before the cone is formed, but this makes sizing more difficult and is not used for hats of solid color. A method which is very objectionable to the men has recently been revived in Danbury after many years' disuse. This is known as "mucking" and consists in the addition of the coloring matter to the water in the sizing kettle so that the sizers must work continuously in hot dye. The men say that it makes the ends of the fingers sore, that hangnails inflame and fester, and that scratches become very painful. They also believe that the steam from the sizing kettles carries with it unpleasant, if not harmful fumes. The vegetable dyes which were formerly used have now been displaced completely by coal-tar dyes belonging chiefly to the azo acid group (Naphtol Blue Black and Naphtol Black B). It is highly improbable that harmful fumes could come from those dyes, but there is one dye stuff, known to the trade as ursol, which is distinctly toxic and is used in some hat factories. This is a paraphenylenediamin, productive of more or less severe dermatitis, and, in susceptible individuals, of bronchial asthma and other symptoms resembling anaphylactic shock.*

The ordinary way of dyeing is to color the shaped and stiffened hat, and a chrome mordant is often required, potassium bichromate being generally used. This is admittedly a source of some trouble in the dyeing room. Chrome ulcers, slowly forming and painless, may develop on the ends of the fingers around the nails, on the nasal mucosa, and sometimes on the margins of the lips. There may also be a severe conjunctivitis. Both mordant and dye may be applied in open kettles, stirred by hand with long wooden rods, or in closed kettles, agitated by a stream of air, or in closed revolving cylinders which dip down into the dye at each revolution. According to the method used conditions vary in the dyeing room, and all extremes may be found in American factories from a Danbury plant in which only hand work is done over open tubs in steam and drip,

* See Curt Gerdon, *Zentralbl. f. Gewerbehyg.*, 1920, VIII, 183.

to a model department in Philadelphia, dry and airy, with its closed cylinders for hats, its closed kettles for fur, and no escape of steam anywhere. Second sizing on machines may follow dyeing.

Pouncing.—Pouncing is the name given to the smoothing process in finishing both soft and stiff hats which is done with the finest of emery by hand or by machine. The pouncing of soft hats is much more extensive and is productive of much more dust than the pouncing of stiff hats. The pouncing of soft hats comes before finishing and the men are called "pouncers," while pouncing stiff hats is a part of finishing and these men are known as "finishers." The soft hat "finisher" may do a little pouncing, but not much. An exhaust is always furnished to carry off the dust and, in the case of the pouncing machines, it is usually quite efficient. These machines are used on brims, the narrow brim being held between two sand-paper covered surfaces. The man's hands are outside. Consequently only a narrow opening is necessary, and the construction of shield and exhaust presents no difficult problem. But crown pouncing is almost always done by hand, and obviously it is much harder to prevent the escape of dust over this larger surface which cannot be so completely enclosed.

To the uninitiated the amount of dust produced by pouncing seems insignificant, and yet enough of it is collected by the exhaust pipes to make it worth while to ship it to fertilizing plants. If the suction apparatus is poorly designed or the draft feeble, fine dark dust can be seen on the face of the pouncer, especially in the folds along the sides of the nose and on the chin.

Finishing.—Finishing consists in steaming and blocking to give the crown the final shape; in drying; in pressing by hand or in a hydraulic press; in singeing; in oiling; and in pouncing. Hot oil and vaseline are used to even up the color; alcohol or naphtha singeing, to finish the surface. The highest temperature to which hats are subjected is in pressing, and it is in this department that mercury is volatilized to a greater extent than in any after drying. Moreover, the finisher must bend down close to the hat while pressing, putting himself in just the position to inhale these fumes. Several authorities hold that the exposure to mercurialism is greater in finishing than in any other occupation of the trade. This work brings in other bad features, carbon monoxid from naked gas jets, naphtha fumes, and silica dust. The heat for the irons is usually provided by gas and the grease is heated over gas, although electric irons are occasionally found. Unless these rooms are very large the heat may be excessive, up to or even over 100° F. The men employed here, classed together as finishers, are regarded as undesirable risks for industrial insurance, and they themselves say that these jobs, although highly desirable because of the good pay, are the most unhealthful of all.

Mercury Vapors.—Estimations of mercury in specimens of hatters' fur and felt were made in the Laboratory of Applied Physiology of Harvard Medical School by Anne Stone Minot (34) for the purpose of discovering how much mercury is lost by vaporization or by treatment with hot water during various processes of manufacture and in this way gaining some idea of the hazard of mercurial poisoning in these processes. The process of Lamholt and Christiansen was followed in general; the organic material was destroyed by means of nitric acid and potassium permanganate, the excess of these reagents removed, and from a faintly acid solution the mercury was precipitated by hydrogen sulphid, dissolved in aqua regia, neutralized, and then (following Volhard's method) reprecipitated as sulphid by boiling with a slight excess of ammonium sulphid. This precipitate was converted into a soluble sodium sulpho salt, $\text{Hg}(\text{SNa})_2$ by boiling with sodium hydroxid, and reprecipitated as sulphid in a form more easily filtered by the addition of an excess of solid ammonium nitrate.

TABLE 2. RESULTS OF ANALYSES OF FELT IN DIFFERENT STAGES OF HAT MANUFACTURE

Specimen	Percentage of Mercury Found
1. Carrotted, dried in oven, cut when wet.....	2.41
2. Carrotted, dried in oven, seasoned three months.....	1.88
3. Sized hat	1.69
4. Finished hat	0.85
5. Blown fur	1.30
6. Cone from former.....	1.06

The specimens analyzed belonged to two lots, the first containing four samples, the second, two. Number 1 was carrotted fur, dried in the oven for yellow carrot, dampened sufficiently to make the pelt pliable, and cut. The second specimen had been carrotted, dried in the oven, seasoned for three months in a storage room, then brushed and cut. It is evident that a decided loss of mercury occurs during this "ripening." Number 3 was fur which had gone through the same processes as specimen Number 2, and had then been blown, formed, and sized. Only a slight loss of mercury occurred during these processes, but in the course of the following stages—blocking, shaping, and pressing with hot irons—the greatest loss of mercury occurs; for Number 4, the finished hat, has only a little more than half as much mercury as the sized hat. The next two samples were from another lot, and were sent to us by request because we wished to know just what was the loss of mercury during the forming process. Number 5 was blown fur, and Number 6 part of a cone from the forming machine. The analyses show an appreciable loss of mercury during forming.

It appears from these analyses that the quantity of mercury to which hatters-furriers and hat makers are exposed is slight, yet this industry is looked upon by Europeans as one of the worst of the poisonous trades, calling for strict regulation and, according to many writers, for the total prohibition of acid nitrate of mercury as a felting agent.

It is in French literature especially that one finds gloomy pictures of the men and women in the fur cutting trade, and ever since 1817 Frenchmen have tried to find a satisfactory carrotting fluid without nitrate of mercury, the use of which might be made compulsory by law. In 1911, Martial (36) investigated the fur cutting trade and found a great deal of mercurialism. There were at that time, he says, from 500 to 600 members of the hatters' syndicate in Paris. Two hundred and fifty of these were hatters-furriers and 60 per cent of them he found to be affected with mercurialism. The mortality from mercurialism was two to three per cent per year. Martial himself examined 49 working at the time and found evidence of mercurial poisoning in 20, although this was during the slack season when only the best workers were left. All carrotters, he believes, acquire mercurialism within five years' time and of the others about 30 per cent are poisoned in five to fifteen years, 10 per cent after fifteen years. He says, "Nobody of course thinks of denying the shocking ('néfastes') effects of the acid nitrate of mercury. Everybody knows it is a poison and recognizes the damage it causes."

The French law of 1898 is very detailed. It forbids the employment of boys under 18 years of age and of women in carrotting. It requires floors to be of impermeable material, clean and in good condition, walls also. The carrotting fluid must be made only at night and in a separate room. Exhausts must carry off the vapors from drying rooms, and the rooms in which skins are stored, carrotted, blown, and cut, must be abundantly ventilated. Carrotters must wear gloves of rubber or heavy leather, and for all who handle the skins after carrotting, the employer must furnish a suit of washable working clothes. Wash basins and soap, and a separate lunch room must be provided, and no food may be kept or eaten in a workroom. A doctor must examine once in three months all workers who come in contact with carrotted fur, and if signs of mercurialism are detected, the worker must be shifted to work which will not expose him further. Yet these safeguards are regarded by the French sanitarians as inadequate and they are leading a movement to prohibit the use of mercury in felt hat manufacture just as they led the movement against white phosphorus in the match industry and the use of white lead in paint.

In 1909 Levitsky (37), a Russian, wrote an article for the *Revue d'Hygiène* of Paris describing a mission upon which he was sent by the Moscow Zemstvo to inquire into conditions in the felt hat in-

dustry in other European countries and to obtain suggestions if possible for a non-poisonous substitute for mercurial carrot, which the Russians were convinced was the source of much industrial poisoning. He gives no facts as to the industry in Russia prior to his journey which was made in 1902, but says that the Zemstvo wished to discover a radical remedy for the terrible industrial disease of hatters, mercurial poisoning. "The question of suppressing the use of mercury in this industry is a question of delivering several hundred thousands of men and women from the suffering caused by chronic mercurialism, from invalidism, and premature death." Levitsky took back specimens of fur carrotted by the Jourde-Lusigny formula (NaNO and KHO followed by carbon and HNO_3) and the Zemstvo of Moscow induced one of the coöperative factories to work it up into felt, which they did with such success that two more factories undertook to carrot by this method altogether, the Zemstvo guaranteeing them against loss for four years. The hat makers of St. Petersburg, Moscow, and Warsaw declared the felt satisfactory and other coöperatives adopted the no-mercury process so that in 1909 Levitsky was able to write that some 67 plants, employing 1,500 workers, were already using the non-mercurial formula and he was hopeful that mercurial carrot would be altogether done away with in Russian factories.*

The industry in Belgium has a very bad reputation. It is in part a home industry, poorly paid, and carried on by the very lowest class of the community. Belgium is the source of hand-plucked skins for the rest of the world and much of this work is done in the homes, where piles of dried skins give off a nauseous odor and the plucked hairs fly over everything. But these are raw skins, not carrotted, and, according to Glibert (14), the work is not unhealthful, filthy as it is, and Belgian women fur cutters do not compare unfavorably with women textile workers. The men who do the carrotting, however, have a high sickness rate, and of those examined by him 66.67 per cent showed symptoms of mercurialism. The effect of mercury upon health can be seen in the report made by Glibert at the International Congress of Hygiene in Washington, 1912:

* Levitsky informed me when I was in Moscow in November, 1924, that the making of felt hats has always been a home industry in Russia, although before the war there were also factories. At present all the work is done in peasant homes, during the months from September to April. Levitsky has found children in these homes suffering from mercurialism as well as adults, for the work is done in the general living room. His twenty-year crusade against the use of mercurial carrot has at last resulted in a prohibitory decree which was promulgated in August, 1924, and is gradually being enforced as the peasants learn the new method. At that time 60 per cent had already adopted it. The carrotting has to be done very carefully or the hair will mat, and it must be dried in the cold, not with heat. However, only two days are required for drying and ripening. The solution of potassium hydrate must have a strength between 6 and 10 degrees Bé.; anything over that renders fur friable.

Occupation	Sex	Health		
		Good	Mediocre	Bad
Processes before carrotting	men 705	91.91%	7.8%	0.28%
	women 938	84.21	15.68	0.11
Carrotting	men 88	63.64	31.82	4.54
After carrotting	men 44	77.37	22.72	
	women 435	68.96	28.96	9.00

In Great Britain serious cases of mercurialism were reported from the hatters' trade during the later nineties, and this led to a governmental inquiry. Mercurial poisoning was brought under the law requiring notification of cases in May, 1899, and by December, 1918, 208 cases had been reported. However, only 46 of these came from the hatters' trade, 27 being from the hatters-furriers, and 19 from the hatters. Forty-six in almost twenty years does not indicate any great danger of mercurialism in the British hat industry.*

The felt hat industry has not been as fully studied in Germany as in most countries; indeed, it seems to have attracted less attention than any other industry involving the use of a poisonous substance. There is a section devoted to it in Weyl's *Handbuch der Arbeiterkrankheiten*, by P. Schulte of Magdeburg, but the information given is general in character, and the greater part is devoted to the effect of the fur dust on the respiratory tract, not to mercurialism.

Teleky (8) of Vienna describes the slow chronic form of poisoning found in hatters as contrasted with the more rapid form which develops in other mercury-using industries where the exposure is more intense. It is evident from his article that the trade is not nearly so harmful in Austria as in some other countries. He examined the workers in two large factories. The first, an excellent place, employed 2,400 men and women, and there he found 12 persons with symptoms of mercurialism while 4 others were at the time incapacitated from the same cause, making 1 in 150 employed. The second factory was distinctly less well managed, and there, among 500 to 600 employed, he found 7 at work with symptoms of poisoning, or about 1 in 80. The larger of these factories, Hückel's Söhne of Neutitschein, I had the opportunity to visit in the summer of 1921 and found it admirable in construction and in management. Teleky's analysis of blown fur showed the presence of 2.338 per cent of mercury.

* While in Stockport visiting felt hat works, I was informed that British carrotting fluids are usually much less strong than those often used in the United States, because of the large amount of cheap felt made in this country from shoddy and inferior fur which requires a strong carrotting solution.

Monti (12) in 1909 published an article on mercurialism among Italian hatters in which he declared that it was very prevalent. Seven out of 12 carrotters had mouth symptoms, one had tremor; 35 out of 50 sizers had marked mercurialism, and nine a slighter form. At present the trade is not notoriously unhealthful in Italy, —partly, perhaps, because much of the fur cutting for Italian manufacture is done in Belgium, partly because conditions, in the larger plants at least, are excellent. The famous Borsalino factory in Alessandria, employing some 2,000, and Valera and Ricci's in Monza, employing 1,200, are striking instances of what can be done to render work in this industry not only safe but comfortable. There are certain features in the Borsalino factory which are superior to anything I have seen in this industry in any country.

The first mention of the manufacture of felt hats in the United States was in 1662, when the Virginia Assembly offered a reward of ten pounds of tobacco for every good felt hat produced from the fur of native animals; and the earliest study of mercurial poisoning in the making of hats was made by J. Addison Freeman, M.D., of Orange, New Jersey, and was published in the "Transactions of the Medical Society of New Jersey for 1860." He reports that during the winter of 1858-59 and the following spring there prevailed among the hatters of that region a disease showing all the characteristics of mercurial poisoning,—swelling and ulceration of the gums, loosening of the teeth, fetid breath, abnormal flow of saliva and shaking palsy of the upper limbs. More than a hundred cases occurred in Orange alone.

The next report is twenty years later, from the same city, Orange. In 1878, L. Dennis, M.D., published a paper in the Annual Report of the New Jersey Board of Health on "Hatting as Affecting the Health of Operatives." The report is admirably complete and deserves far more attention than it has ever received. Conditions in the industry at that time seem to have been very bad, partly because of the use of very strongly carrotted shoddy. In some instances "all hands in the shop within a few days were rendered unfit for work or had their health impaired." He gives the records of 1,546 men, with an average age of 32 years, and an average employment of 12 years. One hundred and two men had a history of tremor in the past, 14 had tremor at the time; 56 had a history of sore mouth, 20 had it at the time; the incidence of these symptoms was highest in hardeners, next in finishers. Out of 168 cases of mercurialism which could be traced to their source in the factory, 107, or 63 per cent, were in finishing; and among 438 finishers then at work, 89 had mercurialism. He insists that the finishing benches should be furnished with exhausts as are the pouncing benches, but there are obviously practical difficulties in the way. He also found:

Among 39 blowers	8 cases of sore mouth and tremor
Among 74 coners and wetters.....	14 cases of sore mouth and tremor
Among 39 hardeners	25 cases of sore mouth and tremor

Curiously enough only two out of 450 cases of mercurialism were in sizers.

Philadelphia, Orange, Newark, New York City, Brooklyn, Yonkers, and Danbury and Bethel, Connecticut, are the principal hat manufacturing cities. The only reports from Connecticut are two short and practically valueless papers written for the Board of Health in 1887. In 1891, Adler of Philadelphia described five cases of mercurialism in hatters which are among the most extreme to be found in the literature. Another American publication which contains histories of very severe forms of this occupational disease is the monograph written by Mrs. Linden Bates for the Women's Welfare Department of the National Civic Federation (17) and issued by them in 1912. This report comprises an analysis of 102 cases of industrial mercurialism occurring in New York City and its vicinity. Most of these had had their origin in the felt hat industry of Brooklyn, Yonkers, Newark, and Orange. Mrs. Bates had already made an investigation of the same industry in Great Britain. It was not possible for the investigators to study the physical condition of the men and women actually at work but they were able to discover a number of cases of mercurial poisoning which had come under the care of physicians chiefly in hospitals and clinics.

In all, 80 cases of chronic mercurial poisoning originating in the hatters' trade were found, and their histories are given as much in detail as possible. With regard to 21 cases, only the diagnosis could be obtained; but the histories of the other 59 show that tremors were present in 40 and localized paralysis in four, multiple neuritis in five. In 14 cases there were psychic disturbances; insomnia; headache; depression; even melancholia, impaired memory, hallucinations; and, in five cases, suicidal tendency. It is interesting to note that salivation is mentioned only once.

As these men were, many of them, the wreckage of the industry, it is to be expected that their condition would be sometimes very serious, but none of the foreign studies of mercurialism in this trade give so extreme a picture of physical degeneration as do this report and the article already quoted by Adler (13).

More recently an investigation was made by Louis I. Harris (21), at that time chief of the Division of Industrial Hygiene of the New York City Health Department, which covers the hatters' fur industry and the manufacture of felt hats in that city. Dr. Harris examined 266 persons engaged in the preparation of hatters' fur, 110 of them being women. Only 17 of the whole number were found to be quite free from physical defects, and all the others had some evidence

of disease. Harris endeavors to be very cautious in his diagnosis, but he found 91 cases of either very marked or moderate tremor of the arms, face and tongue. He also found 83 with marked inflammatory or spongy condition of the gums. Seventy of the 77 carrotters and cutters had black teeth, and 17 had signs of advanced arteriosclerosis. He succeeded in obtaining 33 specimens of urine for examination, and 16 were positive for albumin.

The evidence of mercurialism among hat makers was less striking than among hatters-furriers. Only 81 individuals could be examined, all but 12 of them men: seven had marked tremor, seven more moderate, and 11 slight. Harris does not accept these last as clear cases of mercurialism. Anemia was present in 12 of the 69 men, and marked gingivitis in three.

Harris' summing up of the two industries together is as follows: among nearly 350 employees, 47 or nearly 14 per cent had distinct gingivitis together with marked or violent tremors of the hands, face, and tongue; another 14 per cent had moderate tremor with gingivitis, accompanied in a number of instances by anemia and arteriosclerosis.

The rate of poisoning, especially among the furriers, is very high compared with that reported in recent years from Great Britain and compared with the rates found by Teleky in Austria.

In view of the importance of the hatters' trade in the United States and the importance of mercurialism as an industrial disease, the Industrial Hygiene Department of Harvard Medical School determined to make an intensive study of a typical hatting center with a view to determining the prevalence of mercurialism and of other occupational diseases among those employed in the various branches. Danbury, Connecticut, was selected and Dr. Wade Wright (22) undertook the study. Unfortunately it was not possible to select a group of men for examination who would represent equally the different departments, for while it was easy to approach the members of the hatters' union, the "makers" and "finishers," it was much more difficult to get at the unorganized fur cutters. Then among the organized men there are large numbers of sizers, while the pouncers are few. The hundred who presented themselves for examination were divided between the fur cutters with eight (four of them carrotting), the "back-shop" with 69, of whom 48 were sizers, and the "front-shop" with 23. They ranged in age from 23 to 67 years, 59 being between 30 and 50 years old. Seventy-two per cent had been employed in the industry for more than 10 years, 39 per cent more than 20 years, and 20 per cent more than 30 years. In addition to the physical examination Wright had urine analyses made of 27 and radiographs of the chests of 56. Twenty-one stated that they were total abstainers, but of the remaining 79, many frankly admitted habitual excessive drinking.

The general appearance of most of the members of the group was good. Sixty-nine were rated as of good nutrition; 25, fair; and six poor. Few of the men were emaciated, and most of them were of approximate normal weight.

The color of the skin was good in 81 of the men, and fair in 17. Two men were distinctly pallid. Skin eruptions were negligible. There were observed among the sizers, however, deep indurated calluses of the hands extending from the thenar and hypothenar eminences over the palms and to the finger tips. Eighteen men, 16 of them sizers, showed marked calluses of the type described. Six sizers had developed Dupuytren's contractions, usually of the little finger of one or both hands. A flanger and a curler had similar disabilities.

In looking for mercurial poisoning the following symptoms were held in mind: salivation, dryness of the mouth, gingivitis, a blue line on the gums, tremors, and psychic irritability. In the course of the clinical study, these six symptoms or signs were recorded with the following frequency: salivation, 22; dryness of the mouth or throat, 25; gingivitis (with pyorrhea), 45; blue line, 3; tremors, 61; psychic irritability, 59.

Of the 100 men examined, there were 53 who presented at least two of the above six signs or symptoms. There were other cases in which either a tremor, or marked salivation, or a blue line was noted; but such suggestions of possible mercurialism, however, lacked supporting evidence. Of the 53 cases, 10 were eliminated as questionable for various reasons, such as uncertainty regarding the severity of psychic disturbance or tremors, which left 43 men who, it may be assumed, presented evidence of mercurial poisoning, and of these five should be considered as severely affected, 14 moderately, and 24 slightly.

Among the group of 43 cases with definite signs of mercurial poisoning, salivation was noted in 17, dryness of the throat in 8, pyorrhea or gingivitis in 21, a blue line in two, tremor in 40, and psychic irritability in 37. Fourteen cases presented two of the symptoms, usually tremor and psychic disturbance; 20 cases presented three of the symptoms, usually tremor, psychic irritability, and gingivitis; eight presented four of the symptoms; and one case presented tremor, psychic irritability, salivation, gingivitis, and a blue line.

Ten of the group of 43 men had sore tongues, associated in three cases with salivation. Of 12 who had noted a metallic taste, seven also gave a history of salivation.

In 14 cases there was a suggestion of weakness of the muscles of the forearms, especially of the extensor group. In no case was there marked paresis. Thirteen men complained of numbness, tingling or itching, particularly of the fingers. Sixteen men gave a history

of twitching muscles, most often noted when in bed. Thirteen reported pain in the extremities, especially in the joints of the hands and arms, or in the knees.

Twenty men gave a history of discouragement, 21 of attacks of dizziness, and 19 of insomnia. Psychic irritability, observed in 37 cases among the group of 43, was associated with discouragement in 20 of these cases, with dizziness in 20 cases, and with insomnia in 15 cases.

Eighteen of the 43 had abnormally high blood pressure. Urine analyses in 13 of the 18 cases revealed albumin in but four instances. Edema, usually of the ankles, was noted in ten cases of the group of 43, associated with high blood pressure in six persons, and with albuminuria and hypertension in two. In seven cases there was fairly frequent diarrhea.

This investigation, revealing as it did no less than 43 per cent of mercurialism in a group of hatters selected at random from the men at work in the trade, not invalidated, proves that the use of mercury to carot fur is attended with very appreciable danger.

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CHAPTER 19

COPPER, ZINC AND BRASS

BRASS is an alloy of copper and zinc, usually containing lead in proportions varying from less than one per cent to 13 per cent. The finer varieties, which commercially are sometimes known as bronze (true bronze is an alloy of brass and tin) are composed of two parts copper to one part zinc, but the cheaper the alloy the greater the proportion of zinc, which may constitute almost or quite one-half. Tin may be a constituent also, and arsenic, phosphorus, antimony, and cyanids may be present as impurities. Zinc melts at 419.4°C . and boils at 920°C . to 930°C ., while copper does not boil till about $2,350^{\circ}\text{C}$. (1). It is the volatilized zinc that makes the brass industry a cause of industrial poisoning. The fumes of volatilized zinc are encountered also in zinc smelting, in molding and pouring brass, in brazing, or welding, in galvanizing, in working up zinc from galvanizing tubs, and in oxyacetylene autogenous welding.

Copper.—So far as we know at present copper is negligible as an industrial poison and the ill-health that is found among copper miners or workers with the metal is caused by something else connected with their work,—heat or over-exertion, or irritating dust, or the presence of lead or arsenic mixed with the copper. The copper mines in this country are in the Lake Superior region, in Montana, Utah, California, and Arizona. No occupational disease suggestive of copper poisoning is found in these places. The Montana mines are very hot and there is more carbon monoxid than in the Arizona mines which are not so deep. Two other drawbacks in Montana copper mines are the large quantity of arsenic in the ore and the presence of free silica. Arsenical dermatitis is very prevalent in these mines (see page 208) and the study of 1,018 Butte miners, made by Harrington and Lanza (2) of the Public Health Service, revealed no less than 432 cases of miners' phthisis.

Industrial copper poisoning has been described fairly frequently, and the presence of a green line on the gums and the fact that the sweat may also turn green have been cited as proofs that the copper was at fault, but although these signs are alarming in appearance, they are apparently of no real importance, and for the most part it is possible to trace to some known toxic agent, usually lead, the symptoms which have been attributed to copper. Thus, Roberts (3) describes a case of chronic copper poisoning in a young man of 20

years, who for two and a half years had been grinding brass and who said that at times all the men in the shop suffered from symptoms like his. He noticed loss of weight first; then loss of appetite; progressive emaciation with increasing weakness; tremors on the least excitement; vague abdominal pains, colicky in character; pains in the epigastrium after food; dryness of mouth; obstinate constipation, attacks of dyspnea and faintness on exertion. He was thin, with flabby muscles, slightly jaundiced, and there was a green line, said to be on the gums. Such a symptomatology certainly suggests lead poisoning, and the same might be said of the case described by Goodman (4) as copper poisoning in a man who came to the University Hospital Clinic in Philadelphia. This was a brass worker, 59 years old, who had worked, not as a founder but in a brass factory, for 47 years. He complained of pain in the epigastrium, loss of weight, loss of strength, a "brassy" taste and green sweat. He insisted that the colored sweat would stain his bed sheets in summer after he had bathed, so it could not be attributed to copper dust on his body. Goodman isolated copper, as the sulphid, from stains on the man's shirt and from the urine, 0.0782 gm. being found in 1090 c.c.

These two men were brass workers, and the dust to which they were exposed contained some lead. From a report by Althoff (5) it seems that a very small quantity of lead in brass dust is sufficient to set up marked symptoms in certain individuals. Althoff's cases were in two brass polishers who developed typical and very severe colic after 8 and 14 years' work respectively, although the brass with which they worked contained only one per cent of metallic lead and the wheels were furnished with exhausts.

The resemblance to the ulnar palsy of file cutters, a form of lead palsy which has been described so often in European literature, strikes one when one reads the history of two cases of "metal turners' palsy" reported by Walton and Carter (6) of Boston, in 1892. These men had practically identical symptoms: paralysis with marked atrophy of the muscles of the hands supplied by the ulnar nerve,—namely, the flexors of the little and ring fingers, while those of the other fingers escaped as did the flexors and extensors of the wrist. There were only slight sensory disturbances. The left hand had the little and ring fingers flexed, and the thumb flexed while extension of the wrist was unaffected. Both men had polished brass for many years using the left hand to hold the lathe and cramping the fingers to grasp it firmly. The authors consider it doubtful that there was brass or copper poisoning, inclining rather to the theory of overstrain of the interosseus muscles or pressure on the ulnar nerve. The possibility of lead being the toxic agent is not mentioned.

Lead poisoning seems to be ruled out as a causative factor in a case which Auerbach (7) of Frankfort describes as the first instance

of neuritis due to copper poisoning reported in the literature (1910). This man was working in copper only, not brass. He was a copper-smith who had used a hammer continuously for 25 years, and he suffered from multiple neuritis with pain, weakness, and extreme atrophy of the deltoid, the supra- and infra-spinati and the extensors of the forearm, and a similar but less marked affection of the muscles in the gluteal region. He improved greatly under removal from work, rest and treatment, but the trouble returned when he went back to work.

Negative evidence as to the effect of copper comes from men who have had wide experience with industrial workers. Thus, Houles and de Pietra Santa (8) wrote a report for a technical mining journal on the condition of the population in a part of France, in the Department of the Tarn, where the one industry carried on is copper founding, hammering, filing and polishing. Sigel (17) quotes this report as follows: No other work is done in the village, and many men work 12 hours a day in an atmosphere of copper oxid; yet in ten years' practice the two physicians have never seen any characteristic occupational disease. There is no such thing as copper colic. Hayhurst (9) examined 75 coppersmiths in Chicago and found nothing which he could regard as an occupational disease, and although Hogben (10) of Birmingham attributed the dyspepsia, colic and constipation of brass workers to the copper, and Simon, writing in Oliver's *Dangerous Trades*, says that copper is quite as harmful a constituent of brass as zinc, the British Departmental Committee appointed in 1894 to look into the dangers of the brass trade reported that zinc was the active agent and the greater the proportion of zinc in the brass the more sickness in the foundry.*

Local irritation of skin and mucous membranes is said to follow exposure to copper dust in a new industrial process. A large copper company on the Pacific Coast has stated to me that they have a good deal of trouble from skin irritation among the men who dry and handle finely divided cement copper obtained from the precipitation of the metal from solution by metallic iron. During drying some of this is slightly oxidized. This amorphous precipitated copper is used in the manufacture of metallic marine paints which are applied to the hulls of ships upon the theory that organic life attaching itself to such a surface would gradually oxidize and then render soluble the copper with liberation of poisonous compounds destruc-

* F. B. Mallory draws a connection between hemochromatosis, the deposit in the liver of a pigment derived from hemoglobin and a subsequent necrosis and regeneration of liver cells, and slow chronic copper poisoning such as occurs from drinking liquor condensed in copper coils or from occupations involving exposure to copper dust. He has produced a similar condition in rabbits by prolonged administration of small doses of copper acetate (Mallory, Parker, and Nye, *J. Med. Res.*, 1921, 42, 461).

tive to such life. There is about 0.1 per cent of arsenic in the amorphous copper, no antimony.

The men suffer from a rash like "prickly heat" chiefly on the scrotum, behind the knees, and under the arms, followed by diffuse redness and swelling and troublesome itching. If the dust gets into a cut or scratch it causes inflammation but not so much as does a soluble salt of copper. When breathed in, it causes profuse mucous discharge from nose and throat and a sweetish taste. The possibility of arsenical dermatitis cannot be ignored in this case, small though the proportion be of arsenic in the dust. This same company also produces precipitated copper carbonate, which is applied to seed wheat to control the growth of fungus (bunt or smut), a use which is at present being tested by the U. S. Department of Agriculture and the California University College of Agriculture. The effect of breathing this dust seems to be only disagreeable; it is followed by the perception of an odor or taste or both of putrefying flesh, which persists for a considerable time. Whether any other effect is produced will probably develop in the course of this investigation.

Brass.—Brass poisoning, brass founders' ague, is, according to the present consensus of opinion, caused by the zinc in the alloy, not by the copper.*

The first description in English of brass founders' ague is to be found in Thackrah's famous work "Essay on the Effects of Arts, Trades, and Professions on Health and Longevity," written in 1830. Thackrah tells of an "ague" or intermittent fever attacking the brass founder once a month or once or twice a year, but he did not know its cause. Blandet (11) was the first Frenchman to describe this form of industrial poisoning and he correctly attributed it to the zinc in brass. Some thirteen years later Greenhow (12) made an exhaustive study of the brass industry in Sheffield, Wolverhampton, Leeds and Birmingham, which led him to refer all the symptoms, the ague and bronchial disorders, to the zinc. He asserted that the same symptoms occurred in men who prepared zinc oxid for the painters' trade. Greenhow's conclusions published in 1862 are largely valid at the present time. They are as follows: (1) Brass founders and all workmen who are exposed to zinc vapors are subject to an illness resembling an intermittent fever of irregular type. (2) The symptoms are: nausea, exhaustion, pains in limbs, headache, chills, sometimes vomiting, often fever, always profuse sweating. (3) The frequency and severity of the attacks are affected by the regularity of exposure, for those who work continuously in the trade

* For a thorough review of the literature of zinc poisoning and a detailed description of the metallurgy of zinc and brass in its bearing on brass founders' and zinc smelters' ague, see Philip Drinker's "Certain Aspects of the Problem of Zinc Toxicity," *J. Ind. Hyg.*, 1922-23, 4, 177.

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seem to acquire a certain tolerance which is however only transient, since it may be lost by a short vacation. (4) They are also dependent on the density of the vapors of zinc in the air. Founders suffer most and the higher the proportion of zinc the more sickness. (5) Poor ventilation, unfavorable atmospheric conditions, increase it. (6) There are usually warning symptoms, but sometimes a slight indisposition or the chilling effect of getting into a cold bed may start a sudden attack. (7) Workers in bronze and iron foundries never get it.

The attack begins with a chilly sensation between the shoulder blades, which spreads till the chill is general. The chill lasts twenty to thirty minutes, rarely two to three hours; then there is a stage of slight feverishness, followed by profuse sweating, during which the body feels warm to the touch. Simon (13), writing in 1887, said that there was no fever and sweating was not invariably present. The first to accurately record the temperature during an attack was Czajkowski (14), who found it 39° to 40° C. He lays stress on pains in the limbs, a feeling of constriction in the chest, and a dry cough. During the fever the skin is dry. There may be a slight second chill and febrile attack. Hirt (15) says about 75 per cent of workmen are susceptible and none acquire immunity, but Villaret (16), Greenhow, Simon, Sigel (17), all insist that the acquiring of immunity is very characteristic of brass poisoning, and Sigel says that 70 per cent become more or less immune, but 30 per cent cannot, and must give up the trade. Sigel bases the diagnosis on the knowledge of the man's occupation, the sudden onset, the exhaustion, anorexia, cough, constriction in chest, pains in limbs, headache, chill, shaking, then sweating.

Kisskalt (18) says the first thing noticed is an irritating cough, then in a few hours come backache and malaise, soon after that a chill. The temperature rises to 40° C., the pulse to 120. Formerly about 75 per cent of brass founders had it, now conditions are better and many escape. Immunity may be natural or acquired. Bargerion (19) speaks of a sweetish taste in the mouth, as if a bit of sugar had lodged in the throat, of heaviness in the legs, irritation at the back of the throat, and thirst and fatigue. If then the man can quit work and go out into fresh, warm air, he may escape an attack, but if he stays on or goes out into the cold, a chill will come on. Arnstein (20) was the first to note a polymorphonuclear leucocytosis. (See p. 282.) In a case of Sigel's there was oliguria, the man passing no urine for 12 hours and then only 900 c.c. in 20 hours. There was no sugar but abundant albumin. The next day, however, the urine was quite normal. He found no connection between fever and albuminuria, indeed the presence or absence of fever in different attacks in the same subject were very puzzling to Sigel.

A characteristic of founders' ague, that it is especially likely to

attack the workman on Monday, is usually attributed to his over-indulgence in alcohol on Sunday (Riesman and Boles (21)); but this statement like most of its kind is not based on a study of the habits of the men actually affected, and it is certainly possible that it may be an evidence of the rapid loss of immunity, such as is seen among nitroglycerin and ether workers, who always notice a return of the toxic effects after a holiday.

The mode of action of zinc in brass poisoning is still not entirely clear. Apparently zinc is not poisonous when administered through the mouth. Salant (22) has fed rats and cats with the malate and the chlorid with no effect, not even a loss of weight. Lehmann (23) fed 500 mg. daily for 240 days without any result.

Apparently the active agent in this very definite and characteristic form of illness in men who are exposed to the fumes of molten brass is the sublimed zinc oxid, yet there is no toxic action attributable to zinc oxid so far as can be ascertained by ordinary tests. In discussing the cause, Eulenberg (24) says the effect of arsenic in the alloy must be considered. Hirt and Villaret thought that zinc smelters escaped, and therefore the intoxication must be caused by a combined action of copper and zinc, but Wutzdorff (25) found typical brass chills among the zinc smelters of Silesia. Sigel discusses the possibility of cadmium playing a part but dismisses it because the symptoms of cadmium poisoning are quite different. He was the first to make a human experiment, on himself, in a foundry where he inhaled the fumes and suffered a typical attack, with a temperature of 37° C., pulse 120-130.

The puzzling question as to why zinc oxid, which is usually harmless, should cause damage to brass founders and zinc smelters, attracted the attention of Lehmann; and after trying in vain to get light on it from animal experiments, he persuaded a brass worker, known to be subject to brass ague, to present himself for experimental study, and he also made observations on himself and on two of his assistants. He worked with chemically pure zinc and thus disposed of the various hypotheses concerning carbon monoxid, cadmium, and copper as the active agents in brass founders' ague. Lehmann produced typical attacks with pure zinc fumes and recovered zinc in the urine. The symptoms were as follows: irritation in the throat and trachea, with painful cough, lassitude, weariness, stiffness of muscles, slight arthritic pains, then chills and fever, the temperature rising from 98.2° to 102.2° with a pulse of 106 and respiration 40 per minute. The chill came on usually after a slight exposure to cold, perhaps no more than was experienced by undressing and getting into bed.

Lehmann points out several curious features in this form of intoxication. An amount of zinc oxid which, injected in soluble form subcutaneously, would hardly produce noticeable symptoms (150

mg.), produced, when administered through inhalation, typical ague. The amount excreted in the urine in severe experimental poisoning was small, about 1 mg. in 24 hours, showing probably that there is only partial absorption of what enters through inhalation, although of course much might have been swallowed and eliminated through the feces, an examination of which was unfortunately not made. The symptoms are such as have never been observed in metallic poisoning; but resemble those of bacterial infection: incubation period, chill, fever, sweating, feeling of congestion in the chest, widespread inflammation of the finer bronchioles, in short, a picture of infectious catarrh. On the other hand, the disturbance lasts only a few hours, it is never dangerous, it never leads to pneumonia or pleurisy or arthritis, as would a true infection. The train of symptoms following the injection of foreign proteids comes to his mind in this connection, the dyspnea, chills and fever. Is it possible that the zinc oxid when inhaled destroys bacteria in the respiratory tract and the symptoms are caused by absorption of their bodies? Or is it the absorption of proteids from dead epithelial cells in the lungs? This is the view which Lehmann is inclined to take, and he believes that the oxid of zinc must be held responsible; for when zinc begins to volatilize it does so at a temperature that rapidly oxidizes it. The reason why brass workers suffer more than zinc smelters is that zinc melts at 400° to 500° C., and therefore the heat required to smelt it is not great. On the other hand, in order to make brass, the mixture of copper and zinc must be raised to the melting point of copper, $1,000^{\circ}$ C., and this great heat volatilizes the zinc.

Arnstein (20), a student of Teleky's, produced experimental poisoning in himself and three other men in 1910. Lehmann had found in his experiments with pure zinc that 0.1 to 0.4 mg. per liter was enough to set up typical brass founders' ague and as Arnstein found the air in a foundry during pouring to contain for as much as five minutes about 0.23 mg. per liter, the four men exposed themselves to the fumes in the foundry and in all seven experiments they were successful in producing an attack of ague. There was rapid pulse in all, 116 to 128, a rise of temperature usually over 38.4° C. but not above 38.9° C., and leucocytosis, polynuclear, was seen in every case, the counts running from 12,000 to 16,800. The chief path of excretion is through the feces. Five examinations of urine and feces were made and zinc was found each time in the feces but only once in the urine. The only atypical findings were, in one instance the duration of the fever till the following afternoon, and in one an apparent enlargement of the spleen, which, according to Arnstein, was observed before by Grave in 1907.

Philip Drinker (1) believes that an important element in the production of zinc oxid poisoning is the breathing of the fumes as they are evolved. That there is a very definite physiological differ-

ence in the effects produced by inhaling fumes of freshly burned zinc oxid and those produced by ordinary zinc oxid powder is shown by the numerous reports of investigators who have administered the latter in doses many times greater than the amount absorbed by brass founders without producing anything like the same results. Drinker believes the difference is largely physical, a question of the size of the particles. Ordinary zinc oxid consists of particles that have become flocculated, probably under the influence of humidity, and are large and heavy, tending to settle along the walls of a tube and stick there, while the particles formed by the oxidation of vaporized zinc are dry and finely dispersed and on passing through glass tubes they have little tendency to adhere to the sides of the tube even if there are many sharp bends. This freshly produced zinc oxid is, therefore, in the optimum condition to pass through the nose or mouth into the trachea and down into the lungs without clinging to the tracheal walls.

Zinc Poisoning in Industry.—Brass ague occurs most frequently in founders who are exposed to the dense, whitish green fumes rising from molten brass as it is poured into molds. This pouring may take place four or even six times a day, and even if we accept Drinker's statement that it is only the freshly formed fumes which are active, the amount breathed in during the day's work may be very great. Furnace men have the worst of it, next brass pourers. Braziers also suffer from ague, but not to the same extent as founders. Brazing consists in heating the edges of two metallic surfaces till they fuse, and usually with the aid of a solder which contains brass. It is done sometimes at a forge, sometimes at a bench with a blow pipe, and the fumes are the same in character as those caused by pouring brass. Galvanizing consists in dipping metal which has been pickled with acid into a bath of hot zinc, which is sometimes allowed to get hotter than is usual or necessary, and in this case galvanizers may get brass chills. Another industry in which brass chills have been reported is autogenous welding of zinc sheets. Recently Engelsmann (26) described typical "Giessfieber" in a young man who used an oxyacetylene torch to cut through a heavy sheet of zinc. (See Pfender, page 284.)

Among the zinc smelters of upper Silesia, Seiffert (27) found a form of illness resembling brass founders' ague, but he thought it not identical. The ore in this region contains, according to Tracinsky (28), lead, arsenic, and cadmium, and the fumes from the retorts in the smelters have this composition: zinc oxid 49 per cent, zinc 40 per cent, cadmium 5 per cent, lead 3.5 per cent, and arsenic 0.3 per cent. It is plain that fume sickness from such a combination might present a picture far from typical.

In the zinc smelters of La Salle County, Illinois, Hayhurst found typical brass chills, "spelters shakes" as they are called, though the

ore contains lead as well and cases of lead poisoning are not rare. The process consists in mixing finely ground ore with coal dust and distilling it in a series of baked clay retorts, heated by producer gas. There are tier on tier of these retorts and the top rows are charged first so that the men will be less exposed to the fumes which soon begin to escape. The amount of fume lost in a well equipped American smelter is not great and the men do not suffer from ague so often or so severely as do brass founders.

In British spelter works lead poisoning is far from rare, in fact more zinc smelters suffer from plumbism than lead smelters (29), but zinc poisoning is also found.

The earliest American case of brass poisoning that I have been able to find in the literature is that reported from Osler's clinic at Johns Hopkins by Oppenheimer (30) in 1895. This rather obscure case was very thoroughly worked out and clearly presented. The man, who worked in a bell foundry, had already been under treatment at the Johns Hopkins Hospital for lead poisoning contracted in the course of his work and came back three months later complaining of breathlessness and other symptoms of uncompensated heart lesion. Careful questioning brought out a history of chills, perfectly typical in character, traced by Oppenheim to the zinc in the bell metal alloy, which he found by analysis.

The next thorough piece of work on poisoning from brass in the United States was written by M. H. Sicard (31) in 1905, when there was still some confusion in this country as to the real cause of brass founders' and braziers' ague, and brass polishers' poisoning, although Greenhow and others had made the question quite clear. Sicard gives a review of the English literature and adds to it observations of his own. He points out the importance of lead and also arsenic in the industrial poisoning of brass workers, a statement which cannot be too often repeated and which clears up many a puzzling history. Thus Pietrowicz's (32) case of supposedly brass poisoning was one of such severity that one hesitates to attribute it to brass alone. The man had been on brass work for fourteen years and had, in addition to the chills and muscular cramps characteristic of brass poisoning, an advanced degree of arteriosclerosis with failing memory, constant headache, vertigo, obstinate constipation and anorexia, emaciation, and tremors and atrophy of the muscles of the hands. Certainly one must think of the action of the lead in the alloy in this case.

Pfender (33) of Washington reported in 1914 an unusually serious case of brass poisoning in an autogenous welder who used the oxyacetylene torch in welding and brazing. He suffered frequent attacks of what Pfender supposed to be malaria until he failed to find the parasite. Then the patient told him that his attacks came on only after brazing, not after forging or welding. He would

feel well till he reached the fresh air when he would be suddenly "knocked out," sometimes hardly able to get home. He was exhausted, had pain in the chest, a feeling of rawness in the lungs, and a taste like blood in the mouth, and sometimes pronounced dyspnea, a sharp rigor would come on, and in a severe attack he would be literally stricken dumb, unable to move or call for help. He described the sensation as "like lockjaw." The worst attack had lasted four hours and was relieved only by morphin and atropin. Fever did not always follow the chills and never exceeded 101° F. The pulse was rapid and fairly strong, but he would tremble for hours after the paroxysm subsided. He usually spent the next day or two in the open air and then returned to work apparently as well as ever, but the repeated attacks reduced his weight from 136 to about 118 pounds within a few months. He improved after changing his work so that he was not brazing continuously, but he continued to have light attacks.

Sigel says that about 70 per cent of brass workers get immunity in time, but may lose it if they quit work for a while and then return to it. Hayhurst says that new men or those just back from a vacation are most likely to suffer. The attacks rarely, if ever, come on inside the foundry, but after the man has gone out into the air or after he has reached home. Winter sees a decided increase in the number of men affected, perhaps because the windows are closed and fumes are worse, perhaps because of the cold which acts as the exciting cause of the chill.

In considering what is described as chronic zinc or brass poisoning without typical ague, one must bear in mind the many dangers to which men in zinc or brass works are exposed aside from the zinc itself. Kobert (34) recalls Wutzdorff's finding of lead, hydrogen sulphid, carbon monoxid and sulphur dioxid in the fumes from zinc smelting and warns against attributing to zinc symptoms caused by one or more of these. He says the zinc smelters who are sent to the Bremer Tuberculosis Sanatorium go on excreting zinc in the urine for as much as three months, yet show no symptom except anemia.

In 1879, Schlokow (35), a physician of Upper Silesia, described chronic bronchial catarrh among old zinc smelters, with emphysema, gastric indigestion and liability to intestinal catarrh. The skin was pale or dirty gray, the general condition very poor, and there was a dark line along the margin of the gums. He found a curious nervous disease with partial paralysis of the legs which he likened to tabes dorsalis. Wutzdorff has described conditions in the zinc smelters of Upper Silesia and of Rhenish Westphalia as they were in 1900. Blende, carrying sulphur in great quantity, lead about 1 per cent to 4 per cent, arsenic 0.03 per cent to 0.3 per cent, sometimes cadmium and antimony, is one of the two forms in which zinc

is found, the other being "Galmci," or zinc carbonate. The method is to roast zinc to the oxid and then reduce the oxid. The carbonate loses CO_2 , blende loses sulphur as SO_2 , part of the arsenic as As_2O_3 , but the lead remains, is not volatilized. The smelters of Upper Silesia, according to Wutzdorff (25), have much ill-health, far more than those of the Rhineland, not because the ore is different or the conditions of work are worse, but because they are of inferior physique, more given to alcoholism and with poorer homes and living standard. Wutzdorff finds much lead poisoning among the smelters, 37 cases among 404 cases of sickness treated at the Hohenlohe smelter in 1891 and 46 out of 483 in 1892.

Tracinski (28), writing in 1888 about zinc smelting in Upper Silesia, found several occupational diseases among the men and women employed in this work. Night blindness was caused by the glaring light from the furnaces, chronic muscular and articular rheumatism from the sudden changes from hot to cold, catarrh of the respiratory tract and inflammations of skin and eyelids were caused by the dust. More important were gases: CO which set up headache, dizziness, faintness, nausea, later anemia; SO_2 which irritated eyes and air passages and stomach. Lead he considered a much greater peril than zinc. In 1881 in the Lipine smelter there were 222 cases of lead poisoning which were brought down to 28 by 1884 through reforms in the operation of the smelter. The palsy seen—109 cases in 7 years—affected most frequently the legs. Tracinski believes Schlokow's disease is lead poisoning. He saw transient amblyopia and encephalopathy and six deaths from plumbism.

Seiffert (27) reported in 1897 on conditions in the Antonie smelter in Upper Silesia, where for 12 years he had charge of 1300 zinc smelter men. He thinks such work is followed by slow insidious marasmus. The ruddy color soon vanishes, the man grows pale, anemic; there is a lead line on the gums, he loses appetite, has attacks of indigestion, tearing pains in arms and legs, in the muscles of the back and chest, and along nerve trunks. There is albuminuria and evidence of contracted kidney. Emaciation progresses, indigestion increases, the gait is trembling and swaying, premature senility comes on making a man of 40 years unable to do heavywork. Lead is the chief harmful agent, zinc secondary in importance, then come heat, heavy work and dust. Seiffert demonstrated zinc and arsenic in the urine, lead and antimony in the mucous membrane of the gums. He was surprised to find very little tuberculosis among these men and attributes it to the favorable effect of SO_2 fumes.

The brass industry, not only founding but grinding, polishing, plating, and lacquering, is notoriously unhealthful. Murray (36), in 1900, described chronic brass poisoning among the workers in

Birmingham, especially young women and boys. The symptoms begin with anemia, then the picture presented by the patient when he seeks the doctor is very suggestive of phthisis, pallor, emaciation, complaint of cough, pain in chest, loss of appetite. There is increasing weakness, headache, shortness of breath, dyspepsia, gastric pain, dry throat, laryngeal catarrh, aphonia, metallic taste, cold sweats, intense nervousness. A green line is seen along the teeth where they emerge from the gums, and sometimes a purplish line may be seen along the margin of the gums. Murray doubts that lead can be regarded as the cause, even if lead is present in the alloys. He inclines to think it is the copper, although the zinc cannot be ignored. The victims are polishers, finishers, stampers, etc., but all are working in brass.

The following year Hogben (10) wrote a full description of the diseases of the brass workers of Birmingham. There is much nervous disorder among them, but no characteristic paraplegias. Suckling (37) described a form of ataxic peripheral neuritis which he saw in four brass workers, the incoördination preceding the palsy. It resembled locomotor ataxia without the Argyll-Robertson phenomenon. This recalls Schlokow's description, but most commentators on such findings hold that they should be attributed to the lead in the alloy. In 1902 Legge (38) made a study of the health of the Birmingham brass workers, who were reported to be suffering from anemia, emaciation, and a green line on the teeth. He questioned 233 founders and 210 polishers, and from 22.7 per cent of the former and 11.6 per cent of the latter he heard a history of ill-health which could be attributed to the occupation. The greater the proportion of zinc in the brass the more sickness, and founders suffer more than polishers. Legge believes that there is no real brass poisoning, only zinc poisoning; but because of dust and fumes there is an inordinate amount of tuberculosis.

It must be remembered that brass workers may have to breathe fumes of acid from the pickling tubs, of volatile solvents from shellacs and lacquers; they are exposed to great heat from the crucibles, and they may get dermatitis from the antimony and acute arsenical poisoning from the gas generated if metal contaminated with arsenic is put in the pickling tank. Sicard says that in the "pickling" department of brass shops where brass is dipped in H_2SO_4 the fumes cause cough, pallor, and emaciation, and the men cannot stand it more than three to four years. In the making of the zinc and phosphor bronzes, phosphorus may be added, and though Hayhurst has not found any evidence of phosphorus poisoning in the American brass industry Kaup found a typical case in an Austrian foundry where phosphor bronze was made for cannon.

Hayhurst (9) made a thorough investigation of the brass and zinc industries of Illinois and Ohio, of the former in 1909, of the latter

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in 1913 and 1914. In the course of the Illinois survey he examined 187 brass workers, 146 of whom had been or were subject to brass chills. In the brass industry in Chicago he found a proportion of young men unusually large for a skilled and well paid trade. Out of 1761 men, 1500 or 85 per cent were less than forty years old, and only 17, one per cent, were over fifty years. This is much worse than Tatham's record for 1200 Birmingham brass workers; for he found 10 per cent over sixty years of age: yet he thought that a shockingly low number. Hayhurst's Ohio survey brought to light 124 cases of brass chills, all but nine in foundries, one in galvanizing and eight in brazing.

W. Gilman Thompson (39) speaks of the chronic ill-health of brass polishers and men handling solid brass. Sometimes the symptoms point to injury from the metallic dusts and emery dust in polishing, as in one case which he cites of a brass polisher with chronic bronchitis and emphysema. In other cases the picture presented may be that typical of chronic lead poisoning. Such was the case of a man of 46 years, who for eight years handled bars of brass and copper. He had a lead line, profound anemia, stippling of the red cells, chronic nephritis, and arteriosclerosis.

Zinc chlorid has an effect on the skin which is described by McCord and Kilker (40) who saw cases of it in a wood preserving industry where tars, creosote and zinc chlorid are used. Aside from the lesions attributable to the tarry substances, they noted in all the force of 17 workmen zinc chlorid burns, on hands, forearms, fingers, and rarely on legs and thighs. All the sufferers gave a history of slight injury, such as an abrasion, or a splinter under the skin, or a burn or chapped skin. The typical lesion which then appeared was a small opening in the skin, usually corresponding to the size and shape of the antecedent injury. The surrounding skin looked normal, but on careful examination it was found to be easily removable and the lesion was in reality much larger than the original injury. For instance an injury measuring 4 mm. in diameter would result in impairment of an area of about 12 mm. of skin. On removing the skin it was found that the underlying tissues were white and bloodless, and in the center there was a cylinder of scar tissue, the depth of which depended on the duration of the lesion. There was no sign of infection and little or no swelling. At times some of these lesions were exquisitely painful but others were wholly and continuously painless.

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CHAPTER 20

MANGANESE, ANTIMONY, CADMIUM, NICKEL CARBONYL

MANGANESE

THE first description of manganese poisoning was written as early as 1837 by Couper (*Jour. de Chimie med. de Pharm. et de Toxicol.*, 1837, 3, 2d series, p. 233). He described two severe cases of the disease in men employed in grinding peroxid of manganese in the manufacture of bleaching powder. Three milder cases also developed but the disease was arrested when the men were put on other work. The chief symptom observed by Couper was paralysis of the legs, increasing, and of such a nature that the patient reeled in walking and leaned forward when he wished to walk. There was some weakness of the arms and difficulty in speech and saliva ran from the mouth during speech. There were no sensory symptoms, no tremors, no colic nor constipation, nor disturbance of digestion, and the intelligence was clear.

This observation was completely forgotten apparently, for in 1901 von Jaksch (1) described some cases of "diffuse brain and cord disease approaching the type of multiple sclerosis and characterized by a special etiology." Von Jaksch had three cases under observation at the same time, cases apparently of multiple sclerosis of the brain and spinal cord which were very striking in their similarity, in the fact that they occurred simultaneously, and in certain distinctive features, such as the absence of nystagmus and intention tremor and also the lack of change in the optic papillæ. Other unusual features were the tendency to retropulsion, the motiveless, uncontrollable laughter, sometimes weeping, the monotonous speech and the occasional periods of betterment. But the most interesting one was that all were employed at the same work, the drying of manganese dioxid slime, and all attributed their disease to their work. Von Jaksch rejects the suggestion that contact with manganese compounds produced the disease, because other men engaged in manganese dust did not show similar disease. He was inclined to think that the great temperature variations to which they were daily subjected had brought about the disease in the central nervous system.

In the same year that saw the publication of von Jaksch's article

Embden (2) published his study of chronic manganese poisoning in manganese mill workers and referred back to the early work of Couper which his observations substantiated. He also saw three cases which developed after several months' exposure to the air of the mill. The first symptom he mentions is edema of the lower extremities, then weakness in the groin and in the legs as well as a tendency to stagger and to walk backwards, or to fall forward when going downstairs. Then it became more or less difficult to use the arms, and disturbance of speech appeared and marked disturbance in writing. Embden's description is very detailed and little has been added to the features of the disease as given in this article.

Two years later Friedel (3) gave a description of a very striking case of poisoning which ten years later came under Seelert's (4) observation and was reported in detail a second time. Friedel attributes the disease to manganese dust and advocates the quarterly examination of all workers by a physician entirely familiar with the symptoms of manganese poisoning. He lays stress on the occurrence of salivation, on the importance of individual susceptibility, and on the special danger to mouth breathers.

The next article in the literature, by Seiffert (5), is a discussion of the same case as Friedel's. Then in 1907 von Jaksch (6), accepting Embden's theory of the etiology of his cases of "multiple sclerosis," reviewed them and gave the later history of one. The psychic symptoms, impulsive laughter and weeping, had disappeared. There was no longer alimentary glycosuria; the reflexes were still exaggerated; there was no loss of sensibility; the patient could stand well with his eyes closed, but the gait was most extraordinary, a peculiar spastic-paretic gait in which he stepped on the metatarsal-phalangeal joint. There was absolutely no atrophy of the muscles. Von Jaksch added another case, bringing his number up to four. He noted the mask-like expression so often referred to in later histories.

The first American report of manganese poisoning was presented by Casamajor before the Fifteenth International Congress on Hygiene and Demography which was held in Washington in 1912 (7). He recognized it as a definite pathologic condition affecting the central nervous system with a definite symptom complex, involving principally the mechanism of walking and equilibrium, of toxic origin and "in greatest probability the toxic agent is manganese." Casamajor saw nine cases in men working in the same mill and in the department where the electric separators for the removal of iron from the finely ground ore are situated. He suggested that possibly the high power electro-magnets might have played some part in the causation of the disease, but thought it improbable as there are other places where men work in high

power electric fields and this condition would have been observed long ago if it had occurred.

In 1919 Edsall and Drinker (8) published an article on manganese poisoning occurring in the mill in which the cases seen by Casamajor had developed. At that time the number of cases of manganese poisoning described in European literature was 15. With Edsall and Drinker's, the American figure was raised to 39. One of these was engaged in shoveling Japanese manganese ore into a hopper, very dusty work, and all the rest were employed in dusty parts of a mill where manganese was separated from other constituents in the ore. The crude ore here contains 9 per cent manganese, no arsenic and only traces of lead. The process of separating is dry, the manganese and iron fractions are removed by the use of large magnetic separators, and for this the ore must be dry and exceedingly fine and the dust control is difficult. Chronic poisoning occurs as a result of inhalation and swallowing of manganese dust, the shortest period of exposure before the appearance of definite symptoms being one and one-half months, but permanent crippling has required an exposure of at least four months and five days. Edsall and Drinker believe that absorption takes place probably from the lungs and from the gastro-intestinal tract, and quote Wichert and Harnack as finding soluble manganese salts excreted in the bile. Harnack found excretion of manganese into the intestine, and a small amount in the urine. By feeding peptonate of manganese to an individual with an operative biliary fistula he found manganese in the bile.

Edsall and Drinker summarize the syndrome of manganese poisoning as follows, giving the manifestations in the order of their appearance:

1. A history of work in manganese dust for at least three months.
2. Languor and sleepiness.
3. Stolid, mask-like facies.
4. Low, monotonous voice. Economical speech.
5. Muscular twitching, varying in degree from a fine tremor of the hands to gross rhythmical movements of the arms, legs, trunk and head.
6. Cramps in the calves and a complaint of stiffness in the muscles of the legs, the cramps usually coming on at night and being worse after a day of exertion.
7. Slight increase in tendon reflexes.
8. Ankle and patellar clonus. Frequently by stretching any of the muscles of the body it is possible to elicit rhythmical contractions. Romberg sign is inconstant; there is no inco-ordination.
9. Retropulsion and propulsion.

10. A peculiar slapping gait. The patient keeps as broad a base as possible, endeavoring involuntarily to avoid propulsion. "The shoes are worn evenly and we have not been able to convince ourselves of the pronounced tendency to walk on the region of the metatarsophalangeal joints, a feature strongly emphasized by von Jaksch."
11. Occasionally uncontrollable laughter, less frequently crying.
12. Uniformly absent are any disturbances of deep or superficial sensation, eye changes, rectal, genito-urinary or gastro-intestinal disturbances, reactions of degeneration, blood, urine, and spinal fluid alterations. It is significant that, unlike lead, manganese produces no life-shortening degenerations. Seriously poisoned men are life-long cripples. The metal apparently makes a very definite attack upon some non-vital portion of the neuro-muscular system, destroys it thoroughly, if time for action is permitted, and leaves the victim quite well in every other respect.

Edsall and Drinker saw none of the salivation nor edema described in some of the European cases. Their paper covers thoroughly the literature of manganese poisoning up to that date and the clinical manifestation as shown in their own cases. For the pathology it seems we must wait till typical cases have come to autopsy at the hands of careful observers. It is probable that this will reveal changes in the lenticular nucleus.*

The last American cases reported up to date (January, 1924) were two by Davis and Huey (9). These occurred in the manufacture of manganese steel, not by adding solid manganese to the molten iron, as is usually done, but by first fusing the manganese in an electric furnace. The heat at the charging door of this furnace was so great as to force the escape of a considerable quantity of fumes when it was opened and as much as 18.72 per cent of manganese was found by analysis in the fumes. The first victim was a healthy young Italian, who had worked two years on the furnace when his foreman decided that he had become so dull mentally that

* Hugo Mella of the Neuropathological Department of Harvard Medical School has just published (*Arch. Neur. and Psychiat.*, April, 1924, vol. 2, pp. 405-417) the record of experimental poisoning with manganese which he produced in four monkeys (*Macacus rhesus*) by the administration every other day for a period of eighteen months of manganese chlorid by intraperitoneal injection. The animals developed choreic or choreoathetoid movements which passed into a state of rigidity accompanied by disturbance of motility, then fine tremors of the hands, and finally contracture of the hands with the terminal phalanges extended (typical paralysis agitans contractures). The pathological findings in three animals were most striking in the lenticular nucleus and the liver. In the former the changes consisted in swelling and chromatolysis of the cells, or shrinking and pyknosis, eccentric nuclei and vacuoles, and areas of gliosis, and in one case definite loss of myeline sheaths in the ansa lenticularis. Cerebellum and cord were negative, and the brain cortex showed only a slight but evenly distributed chromatolysis. In the livers of two there was an acute hepatitis with areas of necrosis, small hemorrhages, and beginning fibrosis.

he must be transferred to other work. It was found that he had been growing sleepy and apathetic for about five months, also tremulous even when asleep, disposed to stagger on his feet; he felt insecure and exhibited the typical symptoms of retropulsion, motiveless laughter, a change of expression, muffled speech and a change in handwriting.

The second case was a Hungarian of 32 years, strong and healthy up to his employment, as weigher at the electric furnace. After something over two years he became dull and sluggish and indifferent to his work. He himself said that for a year he had had difficulty in walking, a tendency to propulsion and retropulsion, that his toes and fingers felt numb, his speech was muffled and he felt he was weaker. A mask-like facies was evident, a fixed smile, and he talked with lips slightly retracted and motionless, teeth almost together, his voice low and obscured. He spoke chiefly in monosyllables and seemed to have difficulty in forming a sentence. Indeed it was almost impossible to elicit an answer though he was mentally clear. There was weakening of muscles but little tremor.

In April, 1922, a case of manganese poisoning in an early stage was reported by the same Embden (10) who first traced these cases to their source. He states that health regulations had caused manganese poisoning to disappear from Hamburg till recently when dusty Brazilian ore was substituted for the South Russian ore which could no longer be obtained. A man who was engaged in grinding ore developed first stuttering, then a tremor of the hands, a characteristic "action tremor," especially when he reached up to wash his face. Then walking became difficult, his writing was affected, there was weakness of movement especially in mimicking, but no retropulsion nor propulsion, no irresistible laughter, no vertigo nor headache.

Three cases reported by J. R. Charles (11) in 1922 are, it seems, the first to come from England. Charles says that manganese is used in making chlorin gas, in the manufacture of paints, varnish, enamel, linoleum, in marbling soap and in making steel. His three cases had all been incapacitated from work for some time, from three to five years, and the diagnoses made at the time of their illness were: functional aphonia and functional paresis of the legs; syphilitic myelitis; and functional paresis of the legs. All had a history of increasing loss of strength after employment in manganese (shoveling the ground ore in two cases, grinding ore in the third case), the period of exposure varying from nine months to three years. All had at the time of examination a spastic paralysis of the legs, immobility of the face, monotonous speech (the first could only whisper), changes in handwriting. The first man told a very typical story, of going uphill on his toes and being forced to run downhill faster and faster to keep from falling forward, and of being

obliged to climb stairs on all fours. Here there was a pronounced tendency to walk on the metatarso-phalangeal joints. The men were all living at the time of writing, but all completely disabled by the spastic paresis. Charles agrees with others as to the similarity between this form of poisoning and progressive lenticular degeneration, but the latter is invariably progressive, whereas in manganese poisoning the case remains stationary or improves when exposure to manganese dust has ceased.

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ANTIMONY

In some respects antimony resembles arsenic in its action, and in others lead. Like arsenic, it has an irritating action on the skin and mucous membrane, causing eczemas and other forms of dermatitis, and also inflammation of the mucous lining of the mouth and nose, with hoarseness and a running nose. Von Jaksch (1) says that it is even more irritating to the mouth and throat than arsenic, and more productive of eczema and pustules, but it has much less action on the nervous system. On the gastro-intestinal tract, antimony causes the following train of symptoms: metallic taste, vomiting, cramps, and diarrhea, which are, however, not severe in chronic poisoning such as would occur in industry. In those cases one would expect indigestion, constipation, or looseness of the bowels, loss of appetite and of weight,—symptoms which are very like those set up by lead; but looseness of the bowels is much more common than in lead poisoning, and it may even be dysenteric. Another

distinction from lead poisoning is the presence of sores in the mouth, and of sore throat. It is well to remember that practically all the antimony of industry in this country has some arsenic, and that it is almost always used in conjunction with lead, so that the occupational poisoning which results may easily present a mixed and not a clear clinical picture. Rambousek (2) doubts the occurrence of occupational antimony poisoning, believing that the small quantity of arsenic present as a contamination is responsible for whatever sickness results.

So far as I have been able to discover, antimony is an important metal in only three American industries. These are the printer's trade, including type founding, stereotyping, electrotyping, monotype casting, and linotype and hand composition; the manufacture of grids for electric storage battery plates, especially in molding with lead-antimony alloy; and compounding of red rubber goods.

According to Dr. Earle B. Phelps of the Public Health Service, the proportion of antimony used in type in the Government Printing Office runs from 16 per cent for monotype casting to 3 per cent for electrotype casting. In Germany, Sommerfeld (3) and Lewin (4), and in England Legge and Goadby (5) call attention to the fact that the addition of antimony to lead decidedly increases the danger of lead poisoning; for while antimony volatilizes at a higher temperature than lead, the addition of antimony to lead up to a certain proportion results in a mixture which has a lower melting and volatilizing point than pure lead.

Of course the fact that the symptoms of antimonial poisoning are so like those of lead poisoning makes it very hard to discover how much part antimony plays in any case of occupational sickness which occurs in a man exposed to both, as printers are. I could not find any evidence of antimonial poisoning in an examination of printers in 150 different shops, unless it was responsible for two bad cases of eczema of the hands and forearms in men working at stereotype kettles.

A few writers have tried to make the antimony in type metal (it may form 20 per cent of the alloy), responsible for well-marked and characteristic poisoning in printers. The article of Schrumph and Zabel (6) is often quoted in this connection. These authors believe that there is very little lead poisoning among printers, but that a form of ill-health which is common among them is really an early stage of antimonial poisoning. No less than 20 per cent of printers are supposed by these authors to suffer from it, and it is especially frequent among young apprentices. The symptoms they describe are such as might be caused by any sedentary occupation carried on in bad air and under a good deal of nervous strain, and the symptoms are improved by rest and by exercise in the open air.

A more convincing article on antimonial poisoning in the printing

trade was written by McWalters (7) of Dublin in 1910, describing a form of printer's palsy which he attributed not to lead but to antimony. These were cases of polyneuritis not resembling lead palsy, but the neuritis of arsenical poisoning. McWalters quotes a report of the chief inspector of factories of Great Britain, in which are described similar cases among men extracting antimony from ores. Roberts (8), of Liverpool, described in 1904 what was apparently a case of mixed poisoning from printers' type. The man was a linotype compositor, suffering from tremors of the muscles and from general weakness, probably caused by chronic plumbism, as lead was found in his urine. His chief complaint was of sweating and of tenderness of the palms and soles, and of tenderness of the fingers, which made his work impossible. There were small, flat papules all over the palms, not unlike lichen planus, but without color. Roberts suggests the resemblance between this condition and the skin lesions caused by arsenic. It is, of course, impossible to say whether the antimony in the type metal or the trace of arsenic was responsible.

The use of lead-antimony alloy is very widespread whenever additional hardness must be given to the lead. No cases of suspected poisoning from antimony have been reported in the literature from the making or use of solder, Babbitt, or from the making of molded goods such as the grids of storage battery plates. Probably if any cases have occurred, the effect of the antimony has been masked by the effect of the lead.

The same difficulty is encountered in another industry in which large quantities of antimony are used. Golden and crimson sulphids of antimony, which are really mixtures of the pentasulphid, trisulphid, and oxysulphid in different proportions, are used in compounding red rubber. No precautions are taken and the reddish brown powder is handled so carelessly that the compounders are often covered with it from head to foot; but these men and also those who mix the rubber and compounds in the mixing mills are at the same time handling litharge and lead sulphate, and if they become poisoned, it is much more likely to be from the lead than from the antimony. In fact, toxicologists in general seem to think the sulphids of antimony quite harmless, only Robert (9) believing that large quantities of the dust might cause poisoning in a workman. In order to throw some light on this question the Bureau of Labor Statistics asked A. J. Carlson (10) of the Physiological Department of the University of Chicago to test the solubility of golden and crimson sulphids of antimony in human gastric juice. Carlson used commercial mixtures obtained from the B. F. Goodrich Company of Akron. He found that about 8 per cent of the antimony in the crimson, and about 3 per cent in the golden, went into solution, making it clear that these compounds are soluble in the human stomach and he believes that this solubility is sufficient to

be a source of danger to the men who are obliged to use these compounds in such a way as to expose them to a great deal of dust, or to those who handle food or tobacco with hands smeared with the compounds.

Finally, antimony trisulphid is used in making fulminate caps and according to an expert of the Ordnance Department, some cases of possible antimonial poisoning were reported from that industry during the war, though he said it was impossible to separate the effects of the antimony from those of the fulminate. The symptoms he enumerated, a local irritation of the skin and of the respiratory mucosa, might certainly be due to fulminate.

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CADMIUM

According to Erben (1) the effect of cadmium salts is analogous to that of the zinc salts. There is no positive record in the literature of injury to industrial workers from cadmium fumes except in zinc smelters. Gadamer (2) also says that part of the disturbed metabolism and lowered nutrition of zinc smelters should be attributed to cadmium. Both seem to base their belief on the report published, in 1888, by Tracinski (3) in which he described the industrial diseases of zinc smelter men in Upper Silesia, where the ore contains 3 per cent cadmium, one per cent lead and traces of arsenic. At that time conditions in the smelters were bad and the fumes contained 5 per cent of cadmium, 2.5 per cent of lead and 0.3 per cent of arsenic, to say nothing of the large quantities of zinc oxid. Such gases as CO, CO₂ and SO₂ were also present and the last is said to have caused much irritation of the upper respiratory tract, as well as indigestion, vomiting and diarrhea. The men worked 12-hour shifts and there was a great deal of lead poisoning, 427 cases in seven years.

300 INDUSTRIAL POISONS IN THE UNITED STATES

As for the cadmium, Tracinski quotes Marné (1867) as saying that small repeated doses cause chronic poisoning, which is shown by gastro-enteritis, emaciation, fatty liver, fatty heart. It is impossible to distinguish the symptoms in zinc men of cadmium from those of lead and arsenic, but it is probable that cadmium plays an important part in the production of digestive and nutritional disturbances and leads to early cachexia.

Kobert (4) says that cadmium resembles zinc physiologically, toxicologically and chemically. In man, cadmium sulphate is twice as toxic as zinc sulphate.

A recent article by G. Arbour Stephens (5) tells of the recovery of cadmium but not lead from the liver of an old smelter worker in Wales who had for ten years been drawing compensation for what was allowed to be "plumbism," the chief symptoms being weakness, wasting and a tendency to bronchitis. Autopsy showed marked evidence of chronic interstitial nephritis and the heart was hypertrophied. The liver contained no lead but 0.91 grain of cadmium to the pound and 0.77 grain of zinc. In eight autopsies on spelter workers Stephens found from 0.094 to 0.91 grain of cadmium per pound, and only traces of lead if any.*

Stephens finds that zinc smelting in Wales is attended with exposure to cadmium fumes and the men experience symptoms which are not typical of lead poisoning. There is no typical colic, but marked pain or tenderness at the epigastrium, associated with nausea and some constipation. The patient is dull and heavy, with loss of appetite, thirst, and unpleasant taste in the mouth and a thickly furred tongue. In some cases there is diarrhea. It is probable that the gastritis set up by cadmium prepares the way for lead absorption.

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NICKEL CARBONYL

Nickel carbonyl, the formula of which is $\text{Ni}(\text{CO})_4$, is a gaseous compound of nickel and CO which can be condensed by cold into a mobile liquid, clear, pale straw-colored, volatilizing at room temperature. It has a peculiar sooty odor, perceptible when there is as little as one part in two million parts of air. A Bunsen flame be-

* That this is no proof of the absence of lead from the body is shown by Minot's experiments, which disclosed the fact that lead may be found in large quantity in the bones after it has disappeared from the organs. See page 49.

comes luminous if there is one part of nickel carbonyl to 400,000 parts of air. When the gas is heated to 150° C. it decomposes and metallic nickel is deposited and a volume of CO released which is four times the volume of the original $\text{Ni}(\text{CO})_4$ vapor. These properties have been made use of in the production of pure nickel by the Mond Process, which consists in passing a current of CO over finely divided metallic nickel and then heating the nickel carbonyl to the point of decomposition.

Mond, Langer and Quincke discovered the process in 1890. It was put to use under the name of the Mond Process in 1902, and before its dangerous nature was discovered 25 men were poisoned and three died. The poisoning occurred when a machine broke down and hand work was temporarily substituted. These cases were reported by Mott (1), and led to a thorough study of the toxicology by Armit (2) that same year. Already in 1901 a number of pharmacologists had experimented with this compound and various theories were advocated to explain the nature of its action. Langlois (3) held that it depended on the combination of nickel carbonyl with hemoglobin, which displaced the oxygen and then underwent decomposition, forming CO—hemoglobin (see also (4)). McKendrick and Snodgrass (5) held that nickel itself was the toxic agent, but Vahlen (6) found nickel carbonyl itself toxic. Armit could not discover any combination between nickel carbonyl and hemoglobin, nor could he find that the poisonous properties depended on the carbon monoxid which is liberated. Armit's animals died when their blood had as little as 0.072 per cent of CO and were not poisoned by iron carbonyl which contains more CO than nickel. Rabbits die after breathing for 65 minutes air containing 0.18 $\text{Ni}(\text{CO})_4$ per 1000 parts, but no symptoms appear till some 12 to 14 hours later. Cats and dogs are somewhat more resistant.

According to Armit, the peculiar toxicity of $\text{Ni}(\text{CO})_4$ is due to the fact that it is introduced in gaseous form and deposited as a slightly soluble compound in a very fine state of subdivision over the immense area of the respiratory surface. The nickel is dissolved by the tissue fluids, taken up by the blood, and carried to the organs where it has a specific effect on the endothelium of the capillary vessels, especially in the brain and the adrenals, causing hemorrhages. The effect on the lungs is to cause irritation, congestion, edema, consolidation. It is excreted by the intestines and the kidneys.

The symptoms in man come on immediately after the inhalation of the gas, but are not serious in this stage, only giddiness, slight dyspnea, nausea and vomiting, which pass off rapidly in the open air. Then, after 12 to 36 hours, the dyspnea returns, with rising temperature, cough, blood-stained sputum, pulse rate increased, but not in proportion to the respiratory rate, and the heart sounds are

normal. In fatal cases, delirium of various types develops and other signs of disturbance of the central nervous system, and death on the 4th to the 11th day. At autopsy extensive hemorrhages are found, especially into the corpus callosum of the brain, the lungs, the spinal cord. There is also fatty degeneration of the heart and of the epithelial cells of the liver, and the kidneys, and a fatal pneumonia. Air containing as much as one per thousand $\text{Ni}(\text{CO})_4$ is dangerous (Armit).

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CHAPTER 21

SELENIUM, TELLURIUM, VANADIUM, PHOSPHORUS

SELENIUM

THERE is very little about selenium in the literature. Czapek and Weil (1) say that the effect of this body was first described by Japha in a University of Halle thesis in 1842. Japha had tested it on himself and found that he became constipated and generally emaciated. From experiments on animals he concluded that selenium should be classed with arsenic physiologically, but Kobert likened it to sulphur. Rabuteau, in 1867, found that the selenates of sodium and potassium would cause vomiting and watery diarrhea and a persistent odor of the breath which he attributed to hydrogen selenid. He noted that in mammals the heart beat kept on for three quarters of an hour after respiration had stopped. The very irritating effect of hydrogen selenid has been known since the days of Berzelius.

Czapek and Weil worked with sodium selenid, which is more rapid and intense in its action than the selenate, and which acts just like sodium arsenid, causing first a stage of excitement, then great dyspnea, loss of reflexes, convulsions and death, the involvement of the heart being very slight.

Gadamer (2) says that toxicologically selenium resembles arsenic, that H_2Se is very irritating when inhaled and causes in animals edema of the lungs, while selenious acid, H_2SeO_3 , is very toxic, causing a fall of blood pressure, vomiting, watery stools, paralysis of the central nervous system, convulsions and death. Selenic acid, H_2SeO_4 is somewhat less so. Mead and Gies (3) call attention to the resemblance between tellurium and selenium, as did Czapek and Weil. Both are changed in the body to the methyl compound and it is this, methyl selenid or tellurid, which gives to the breath the garlic odor, so universally noted after exposure to either of them. Tellurium, however, suspends the sweat function, while selenium does not, and selenium is less quickly excreted than tellurium. (Czapek and Weil.)

In 1917, when I was making one of many excursions into that most interesting center of occupational poisons, Perth Amboy, New Jersey, I came on what was to me an unknown industrial poison, selenium. The physician who told me about it said that lately some men from the big copper works had come to him complaining

of bronchial irritation and gastro-intestinal disturbances and he had noted a strong garlic odor on the breath of all, yet they were not eating garlic. One man, more intelligent than the others, told him that they were working with selenium.

In an interview with one of the chemists of the copper company I was told that the garlic odor of the breath was the most marked symptom and much the most persistent. Even after it has passed over, if the man gets a cold in the head, it will return. There is sometimes pain in the abdomen, vomiting, pain in the lumbar region, but not commonly. The effect on the nose and throat is like that of a "rose cold," with sore throat and fever. There is no anti-sudorific effect, on the contrary the men often complain of night sweats.

In this plant selenium-containing ore is crushed and leached with water, the selenic acid is dissolved out and then precipitated in the form of sulphate by SO_2 gas. This is then dried, crushed and powdered and sometimes melted, though apparently it is not necessary to melt it, the same results may be obtained without. My informant considered the melting process the most dangerous for the workmen, but dust is bad, as well as fumes. Selenium is used for ruby glass and for removing the greenish color from ordinary glass to whiten it. It is well to remember also that selenium is likely to be present along with arsenic in sulphid ores, such as iron pyrites.

Poisoning by accidental ingestion of selenium was described by Rosenheim and Tunnicliffe (4) in London in 1901. They had an opportunity to study an epidemic of poisoning from beer which contained selenic acid. Paresthesias, erythromelalgia and melanosis are described by them.

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TELLURIUM

According to Kobert (1) tellurium and selenium are physiologically like arsenic, chemically like sulphur. They are changed in the body to the methyl compounds, methyl tellurid and methyl selenid, which cause a garlic odor to the breath. Neusser (2) first noticed that tellurium caused suppression of the sweat function of the skin. In 1899 Lenher (3) of Yale was working with the metal, tellurium, fusing it, and he discovered that even a slight exposure to the fumes would bring about the garlic breath which was very persistent. He also found that breathing large quantities caused great depression and weakness and somnolence. "One day

after having fused metallic Te in the open air for several hours, I was so overcome . . . that I slept soundly for eighteen hours, although I had meant to lie down for only a short time." Obstinate constipation and often nausea also troubled him, but no vomiting. Lenher then induced Mead and Gies (4) to study the physiological effects of tellurium on dogs. They found that metabolism was practically unaffected with non-toxic doses, the urine was brown but otherwise normal. Large doses retarded gastric digestion, induced violent vomiting and loss of appetite and somnolence. Methyl tellurid appeared invariably on the breath within a few minutes, even after a very small dose. A small dose was also sufficient to arrest the secretion of acid in the gastric juice and to increase the secretion of mucus. After large doses there was restlessness, weakening of reflexes, somnolence, diarrhea, paralysis, unconsciousness, and death in convulsion from asphyxia caused by paralysis of respiration.

Recently the occurrence of tellurium poisoning in industry has been studied by Shie and Deeds (5) of the U. S. Public Health Service. They had an opportunity to examine in the Fall of 1918 thirteen men who were employed in an electrolytic lead refinery where tellurium was present as impurity in the ore. Of the thirteen men examined, seven showed evidences of tellurium absorption as indicated by garlic odor to the breath, the sweat, and the urine, by dryness of the mouth, and by a metallic taste. Five of these had a considerable inhibition of the sweat function, and the two who did not had worked only two weeks. Three of the five had a dry, itching skin, anorexia, nausea, and some vomiting, and some degree of depression or somnolence. They considered that these last showed evidence of mild tellurium poisoning. Shie and Deeds found that the ingestion of a single dose of two grains of tellurous oxid was followed by dryness of the mouth, metallic taste and somnolence, lasting for two or three days, and a garlic odor to the breath persisting two and a half months. They tell of a man who spilled a small container of tellurous oxid and while scraping it up from the floor on to a paper without allowing his fingers to come in contact with it, absorbed enough tellurium (presumably through the respiratory system) to give a garlic odor to his breath for over a week and a bitter taste in his mouth for nearly two days. It is interesting to note that only two of the thirteen workmen examined had been employed as long as a year. The one who had worked for the longest period, two and a half years, was exposed only at rare intervals to the hazard.

Tellurium has not yet been used to a great extent in industry. According to Shie and Deeds, its largest use has been in the glass industry; for it gives a blue, red, or brown color to glass, depending on the method of its use. The reducing property of tellurium has also been utilized to a small extent, at least experimentally, in the

steel industry where it functions in much the same way as coke. It is, however, the occurrence of tellurium as an impurity in copper and lead ores which gives it importance as an industrial poison. The electrolytic refining of lead which carries tellurium is accompanied by the formation of fumes of hydrogen tellurid and dust in the form of tellurous oxid and the tellurates. The men who are exposed are those working around the blast furnaces where the slime from the electrolytic tanks is treated to remove the doré metal. The temperature in the blast furnaces is about 1200° to 1400° F., and the fumes given off probably contain hydrogen tellurid. Tellurium was also present in the dust about the furnaces, probably in the form of the oxid and tellurid.

It is likely that the use of tellurium will increase in the future; for many research organizations are searching for ways in which it can be utilized on a large scale, and at present at least one large corporation has erected a plant for the sole purpose of isolating and refining tellurium. It is possible that we may later encounter the severe effects of tellurium poisoning in men such as have been shown in laboratory animals (Shie and Deeds).

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VANADIUM

Kobert says that vanadium is more like phosphorus than any other metal in its chemical and physiological properties. Research on vanadium has been carried on in England by Priestley first, then by Gamgee and Larmuth. Priestley said that sodium orthovanadate acts like arsenic; Gamgee and Larmuth administering it to cold-blooded and warm-blooded animals by mouth and under the skin, produced paralysis of the vasomotor centers and of the heart and severe irritation of the gastro-intestinal tract.

In 1911 Dr. W. F. Dutton (1) of Carnegie, near Pittsburgh, published a paper describing vanadiumism in men employed in producing various compounds of the metal. Apparently vanadium chlorid and trioxid are used as mordants in printing textiles and the trioxid is also used in the manufacture of steel in making easily malleable and ductile alloys. Dutton finds that it is the production

of the trioxid that causes the most trouble. Laborers in reduction plants who are exposed to the dust and fumes suffer from chronic poisoning. Anemia, a peculiar cachexia, is an early symptom, preceded by an increase in the red cell count and in the hemoglobin, followed quickly by a fall. There is evidence of the destruction of red blood cells. A dry, irritating cough, paroxysmal, is very characteristic, sometimes so severe that hemorrhages result. Such hemorrhages may even be fatal. Susceptibility to tuberculosis is much increased by vanadium poisoning and men should not remain long at the work. Emaciation, cough, pallor, irritation of nose, eyes and throat, are always present and in some cases anorexia, diarrhea or obstinate constipation. Albumin and casts and blood are often found in the urine.

A long exposure to the poison leads to fine tremors of the hands and fingers, to failure of sight, vertigo, hysterical manifestations, even melancholia. The metal may be isolated from urine, sputum, feces and saliva. If serious renal, nervous, and lung involvement are absent, the outlook is good, but fatal terminations are not infrequent.

So far as I have been able to find, this is the only article on industrial vanadiumism in the literature, yet apparently it is a poison with severe effects, and it is used in an important industry, and in a town which is not off in ultima Thule, but in one of the largest industrial centers in this country, the region around Pittsburgh. It is only another instance of the occupational hazards in American industry about which the medical profession at large has no way of knowing anything.

Dr. Dutton tells me in a personal communication that the plant near Pittsburgh is one of two in the United States producing vanadium compounds, not using them in manufacture. He saw many cases of serious poisoning from these compounds and it was not at all unusual for a man of excellent physique to break down after six to eight weeks' employment and die of what the company doctors called quick consumption.

In 1919, I visited the larger of the two plants, one in which Peruvian ores rich in vanadium are, by an alumino-thermic process, reduced to an alloy, ferro-vanadium. The ground ore comes in sacks and the emptying of these sacks and the charging of the furnaces is admittedly a dusty process. Physicians interviewed said that men employed here always had a cough. The alloy runs out hot, but not fuming, so it is said. The only use for vanadium at present is the steel industry, to make ductile steel. Little information of value could be obtained on the spot. The physicians of the village, all employed by the company, did not believe that the effect of working with vanadium dust was any worse than that of any dust, purely a mechanical irritation. On the other hand, a physi-

cian in charge of a near-by hospital said that the dust caused an infiltration of the lung, with moist râles all over the chest, yet no rise of temperature. He had made an autopsy on the body of a man who proved to have only a low-grade pneumonia, not enough to account for his death, and he was inclined to think that there was a poison in addition to the local effect on the lung.

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PHOSPHORUS

Lucifer matches were first made in Europe in 1833 and twelve years later Lorinser (1) made the first report on a hitherto unknown disease, chronic phosphorus poisoning, which the Germans came to call phosphorus necrosis, and the English, phossy jaw. He described 22 cases from the match factories near Vienna and soon after that similar descriptions began to appear in the French, English and German literature and by the middle of the century practically every civilized country had discovered this new occupational disease. The first American case was reported in 1851, about fifteen years after the first patent for the manufacture of lucifer matches was granted to a man in Springfield, Mass., in 1836. It is easy to understand why it took so long to recognize the effects of this poison; for it is very slow in its action, and it attacks only a minority of those exposed, and its mode of action was not known to physicians at that time; so that, as with every new poison, there had to be a goodly number of cases before the connection between disease and occupation was discovered.

Matches are made from three kinds of phosphorus,—white or yellow, red amorphous, and the sesquisulphid. The old lucifer, "strike anywhere," match was made from white phosphorus and it was then that poisoning occurred; for red amorphous phosphorus, used in making safety matches, and the sesquisulphid, which is now used for strike-anywhere matches, are not poisonous. White phosphorus is volatile at room temperature, giving off fumes chiefly of phosphoric oxid together with phosphorus and a little phosphorous oxid. These fumes have a solvent action on human teeth, both when in direct contact with the teeth and when dissolved in the saliva, according to experiments carried on by Thorpe (2) of England. Thorpe's analysis of fumes in a match factory showed that at a dipping table covered with phosphorus paste there was 0.2 mg. of phosphorus to 1,000 liters of air, and in the boxing room, 1.2 mg. Then he analyzed the wash water used by workers at the end of the day and found that there was an average of 4.2 mg. per head per

ten hours work. The regulations that used to be in force when these matches were still made and employers were trying to protect the workers were very detailed and strict, including prohibition of gum chewing or candy eating during work, or drinking from a glass of water that had stood on the working bench, or putting the fingers in the mouth, or using a toothpick.

Industrial phosphorus poisoning is known as phossy jaw because of the swollen jaw, so conspicuous a symptom in almost all cases. It is the most distressing of all the occupational diseases, not because it is so dangerous, for only a small proportion die, or because its onset is sudden and violent, on the contrary, it is very slow in development, and it is never very prevalent, for it attacks only a few of those exposed. But it is frightfully painful, painful with that nerve-racking quality that belongs to pain in the teeth, and it is accompanied by a foul, fetid discharge that makes its victims almost unendurable to others. It is obstinate and chronic, the treatment is agonizing, and the final result is a distressing disfigurement. It is probably this disfiguring effect, plain to every observer, that has made phosphorus poisoning so notorious and led to determined efforts for its abolition in every civilized land.

The trouble starts usually in a carious tooth, but phossy jaw has appeared in toothless men (Andrews (3)). Usually the fumes soften the carious tooth and penetrate to the periosteum of the jaw-bone, either the upper or lower, setting up a partial necrosis, and this leads inevitably to a suppurative inflammation because of the constant presence in the mouth of suppurative organisms. Abscesses form and eventually, the periosteum being destroyed, the bone undergoes necrosis.

The experiments which Wegner (4) in 1872 made on animals showed that under the influence of phosphorus fumes there occurs a thickening of the subperiosteal bone at the expense of the Haversian canals, narrowing them and thus partially shutting off the vascular supply to the bone. Layers of very compact tissue are laid down in the region of the epiphyseal cartilages. In the jaw bones there is an enormous thickening of the periosteum and so much swelling of the soft parts that the animal can no longer open its mouth. Necrosis, with softening and sloughing, is found only when there has been an injury to the mucous membrane leading down to the bone. The same fact was established by the earlier experiments of v. Bibra and Geist (5.) It is only exposure to fumes that sets up these changes in animals; feeding them phosphorus has no such effect.

Twenty years after Wegner, Riche (6) discussed these experiments and pointed out the bearing which later studies in bacteriology have had on our conception of phosphorus necrosis. The osseous changes, Riche said, were attributable to phosphorus, but the necrosis was caused by the action of micro-organisms on this changed tissue.

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Phosphorus produces changes in all the bones, but necrosis takes place in the bones of the jaw because they, more than any, are exposed to the entrance of pus-forming bacteria. Teleky (7) also emphasizes the importance of the secondary effect of pyogenic organisms in the case of phosphorus necrosis and believes that a careful examination of the histories of patients with so-called "phosphorisme" would show that the cachexia was due to chronic sepsis or to tuberculosis.

The effect of phosphorus on the periosteum in lowering its resistance to infection is seen in those cases, of which there are several in the literature, where the necrosis developed long after the person had left the atmosphere of phosphorus fumes. In the French factory at Trélaze the use of white phosphorus was discontinued in 1894, but three years later a pronounced case of necrosis developed. V. Bibra and Geist reported the case of a 23-year-old girl who worked a few years in a match factory and felt no ill effects except an occasional toothache. A year after she left the factory she was seen by the authors and was then in an indescribably terrible condition, dying of sepsis.

The changes in the periosteum of the jaw-bones that constitute phossy jaw may in exceptional cases occur in the periosteum of other bones and lead to an abnormal fragility of the long bones which is shown by "spontaneous fracture." Cases of this form of chronic phosphorus poisoning have been reported from England, France, Austria, Switzerland, Belgium and the United States. A very striking case of destruction of the periosteum was reported by Wegner. A young man, 19 years old, had recently left the match factory in which he had worked since he was four years old without any symptoms of poisoning, either local or general. He was injured by the wheel of a wagon passing over his leg and received two flesh wounds not extending to the bone. Gangrene set in, necessitating an amputation above the knee-joint, during which it was discovered that the periosteum of the femur was loosened and dead bone protruded from the wound. The destruction of periosteum increased, extending up the thigh, and the man died of sepsis on the sixth day. Wegner found at autopsy a slight general hyperostosis of the cranial bones, an ossifying periostitis of the alveolar processes of both jaws, and bony deposits on the epiphyses of the long bones.

The first symptom of industrial phosphorus poisoning is toothache which increases in severity, and, if the tooth is not pulled before the inflammation has reached the periosteum, becomes excruciatingly painful. After extraction, or after the pus has broken through and pressure is lessened, the pain is relieved. It is characteristic that the extraction cavity does not heal quickly, and if the worker returns to phosphorus fumes before it is completely closed, the inflammation spreads rapidly. All the symptoms of suppurative inflammation

with absorption of the toxic products appear and form the so-called systemic phosphorus poisoning, which is really only a septicemia; for the effect of the phosphorus is to cause necrosis of the bone and the rest is due to secondary infection.

If the lower jaw is the one affected there is an active proliferation of periosteum and formation of callus, at the same time with the necrosis and sloughing, and this gives the jaw a thick, swollen look; but in the upper jaw there is little effort at repair, and the dead bone usually comes off in fragments, while in the lower jaw a sequestrum is formed. Fistulae bore their way through from the abscesses, those from the upper jaw usually burrowing through to the mouth and discharging there, while those from the lower jaw break out on the cheek or neck.

The greater number of victims of phossy jaw do not die, but after a year or two healing takes place with the loss of more or less bone from upper or lower maxilla. Sometimes this loss is great, involving a large part of one or the other jaw bones, or even the whole bone. In the worst cases it has been necessary to remove all of both jaw bones. Andrews reported such a case from an American factory, the man being unable to eat anything but liquid food for the rest of his life. More serious results are extension of the suppuration to the orbit with loss of the eye, and extension to the meninges with development of meningitis.

This form of poisoning is slow in onset. Oliver's (8) cases had worked in match factories from 7 to 15 years before necrosis appeared. One group of 82 German match-makers with phossy jaw had averaged 6.6 years' employment; another of 87 had averaged 5 years. In Austria, 41 cases were reported in men working from 11 to 20 years, and 13, for over 20 years. As is true of all poisons, some extremely susceptible individuals are found in the phosphorus match industry who have succumbed to the effects of the poison very quickly. One of Lorinser's cases had worked only seven weeks. Garman (9), in England, saw nine fatal cases in youthful workers who had not been exposed many years.

In all countries the majority of the cases are in men, not from any difference in susceptibility, but because the most dangerous work is always given to the men. The duration of the disease is long, from one to two years in mild cases, many years in serious ones, and recovery from serious poisoning is accompanied by more or less distressing deformities, resulting from the loss of the bony structures of the face and the contraction of the scar tissue. The mortality is about 15 to 20 per cent, death being caused by septicemia which may be rapidly fatal, or, if chronic, may result in the septic cachexia which used to be called systemic phosphorus poisoning before the study of bacteriology cleared up its real nature. Only a small proportion of those exposed acquire phosphorus poisoning. In the

Silesian factories there were in 20 years, 70 cases among 600 workers; and in the French Government works practically the same proportion, in 21 years, 70 cases among 620 workers.

Fortunately phosphorus poisoning in match manufacture is a thing of the past. Its abolition is an interesting story. Because the effect on the victims was so disfiguring nobody could shut his eyes to the facts, the poor creatures with distorted faces could be exhibited on the platforms at mass meetings and the whole audience won over to the cause of the abolitionists. If only lead and benzene did their work on the human face, modern industry would be much safer than it is now. Abolition, of course, did not come easily. All sorts of preventive measures were first tried, the British and the German regulations being very elaborate and detailed. In England not only were the factories constructed according to government requirements but the employer was restricted as to the proportion of phosphorus in the paste and was required to furnish tooth brushes, mouth wash and free dental service. The French, as usual, were for abolition of the evil, impatient of halfway measures—as they are now with regard to white lead in painting and acid nitrate of mercury in felting fur for hats. It was Finland, however, which took the first step, abolishing the use of white phosphorus in 1872, and Denmark soon followed her example. The fact that match manufacture is a government monopoly in France made the scandal of phossy jaw and the expense of compensation a matter of public knowledge, and by 1898 the French Government was obliged to abandon the use of this form of phosphorus. This action was made possible by the discovery in that country that the non-poisonous sesquisulphid could replace white phosphorus in the manufacture of strike-anywhere matches. After that the other countries of Europe followed suit, one by one, until in 1906 it was possible to bring together all the important ones in the “Berne Convention” forbidding the manufacture and the importation of white phosphorus matches. Thus for the first time, and as yet for the last, a notorious danger in industry was legislated out of existence.

The history of this industrial disease in the United States was quite different. While the phossy jaw of match workers had agitated every European country for decades, had been the subject of many eloquent protests, had been debated in parliaments and finally been made the ground for an international agreement for the abolition of the use of white phosphorus, the United States went on for years serenely sure that it was quite free from this peculiarly painful and crippling industrial disease.

It is true that a case of phossy jaw was discovered as early as 1851, some eighteen years after the beginning of the industry in Massachusetts. The patient was treated in the Massachusetts General Hospital and the hospital record is admirably thorough and very

interesting. It describes a necrosis very far advanced, a swollen lower jaw, bloated face, eyes dull and staring, breath very fetid, and half a dozen fistulous openings along the lower jaw discharging offensive pus. It was a very typical case, in its onset and termination, as well as in the lesions produced. The onset was slow; for the man had worked 24 years making paste and dipping matches and he had had no trouble at all until 18 months before he came to the hospital, and then he had only a pain in one of the lower incisors. He lost the tooth and went back to work, and it is the general verdict that going back into the fumes of phosphorus with an extraction wound not fully healed greatly hastens the course of the disease. Later entries in the hospital showed extension of the process in the upper jaw and an increasing toxemia from which he died some six months later.

After this almost nothing from authentic sources was heard in this country. Andrews speaks of a pamphlet published in 1855 by a New York physician describing nine serious cases of phossy jaw in that city, and also of an article in the *New York Evening Post* of 1864 which told of twelve cases. But the belief held by medical men and by the general public during the nineties and the early years of this century was that phossy jaw never occurred in American match manufacture because the factories were so superior to the European and the employees so much better paid and more cleanly and better fed.

Quite accidentally in 1902 investigators for the Federal Bureau of Labor in the course of that extensive inquiry which the Government made into the conditions of women and children in industry * came upon some 16 definite cases of phosphorus poisoning in women and young people and were told that it was far from being a rarity among match workers. As a consequence of this John B. Andrews was commissioned to make an investigation under the auspices of the American Association for Labor Legislation and of the Bureau of Labor in order to determine the extent of the evil in this country. He discovered that in the 15 factories which he visited (there were only 16 altogether in the country) white phosphorus was always used and 65 per cent of all the operatives were exposed to its fumes. Among the 3,591 employees, 1,253 were women, and of these 95 per cent were exposed, while of the 314 children under 16 years of age 83 per cent were exposed.

Andrews not only visited the match works but interviewed doctors, hospital personnel, and dentists and visited the homes of the workers. He found that three factories yielded a total of 82 cases of phosphorus poisoning. In two other factories at least eight perfectly authenticated cases, and probably three more, had occurred in one year. In

* Woman and Child Wage Earners. Rep. to the U. S. Congress by the Comm. of Labor, 1910-11.

one small factory, records were secured of more than 20 serious cases, which had occurred during the past 30 years, many of them requiring the removal of an entire jaw. One of the most modern of the plants yielded records of 40 cases and 15 of these had resulted in permanent deformity through the loss of one or both jaws. In all, the records of over 150 cases were secured, with four deaths. Some of his cases deserve special mention, coming as they do from an industry that was supposed by everyone to be quite free from occupational disease.

One man lost both bones of the upper and lower jaws, and lived on liquid food for the rest of his life. He had a horribly fetid discharge. In another, the suppuration extended to the bones of the orbit and the man lost his eye and finally died after great suffering. A woman was so much disfigured that she shunned everyone and became melancholy and eccentric. Andrews also found instances of the *fragilitas ossium* described by European observers.

This report was published in 1909 and at once aroused attention. The American Association for Labor Legislation undertook the task of framing and securing the passage of the only sort of law for the abolition of white phosphorus in industry that our Constitution will admit of, namely one based on the revenue powers of the Federal Government. The Esch law imposed a tax on white phosphorus matches which would make their manufacture as costly as that of sesquisulphid matches. The Diamond Match Company, which held the patents for the sesquisulphid process, then threw open to the whole country the use of the process, which generous action removed all valid objection to the law and it was passed.

The most interesting points about this history of phosphorus poisoning are that it proves that very serious poisoning may exist in an occupation, at least in this country, without the medical profession knowing anything about it; that all possible hygienic measures may prove to be unavailing for the prevention of certain kinds of industrial poisoning; that when this proves true the only thing to do is to work for abolition of the compound in question; and that it is possible, through the arousing of public opinion, to bring about such abolition in all civilized lands, even when the industry involved is large, important, and influential, and even a lucrative government monopoly.

Twenty years' experience in the making of lucifer matches with phosphorus sesquisulphid has led the Swiss government to consider abandoning the medical control of such factories, and the industrial physicians are in entire agreement with this proposal.

Legge (10), in a recent report of the British Factory Inspection Service, reviews the experience in that country since the change from white phosphorus to the sesquisulphid. No cases were reported till 1915 and then a man who had developed necrosis of the jaw

after many years' exposure, died. Between 1915 and 1918 there were 11 new cases reported, all of men employed in the condenser department of a plant producing white phosphorus or in the conversion of white to amorphous. When these men were finally seen in 1919 nine were said to be fit for any sort of work, but two were in a condition of malnutrition. The latest case reported in England is rather unusual, for it developed after only four years' exposure. The man worked in a room where phosphorus sesquisulphid is dried and he was never exposed to fumes except when there was an accidental ignition of the matches.

There are a few other possible sources of industrial phosphorus poisoning. During the war white phosphorus was used in the making of incendiary bombs, and although we have no record of any cases of phossy jaw in that industry in the United States, there were two typical cases in France with almost complete necrosis of the maxillary. The making of fireworks, especially of giant torpedoes, is said to involve the use of white phosphorus and from time to time a plant is found to be using this process. A personal communication from John B. Andrews informs me that there is at this moment * under treatment in a Philadelphia hospital a girl of 19 years who worked for three years in a fireworks factory in Maryland and has suffered all this last year with severe pain in both lower jaws. Resection has had to be practiced on both of the lower maxillary bones. Andrews also found a young man who worked as a mixer in the same factory, mixing 14 to 18 batches a day and using 24 sticks of white phosphorus in each. He has had slight necrosis on both sides of the lower jaw, with removal of several teeth.

Aside from this, the only other source of phosphorus poisoning of which I know is the making of phosphor-bronze. An analysis of these bronzes published in *Metallurgical and Chemical Engineering* in 1914, shows that they contain from 0.068 per cent of phosphorus up to 0.813 per cent. No case of poisoning has been reported from the industry in America, but it is well to bear this source in mind for Kaup found a case of phossy jaw in an Austrian phosphor-bronze works and the proportion of phosphorus in the bronze was only 0.76 per cent.

Ferrosilicon may give off phosphoretted as well as arseniuretted hydrogen, as was reported by Glaister at the International Congress for Industrial Hygiene in Brussels in 1910. Just recently a curious instance of this came to light in Germany (11). Four adults living over an old storage place for ferrosilicon sickened with symptoms of what was supposed to be food poisoning, and three died. A cageful of birds kept in the same room also died, and this led to a doubt of the diagnosis and a thorough investigation of the premises.

* March, 1924.

It was then discovered that a few days before the first man fell sick a new consignment of 10,000 kilograms of ferrosilicon had been added to the old lot. It was a rainy day, and some boxes were broken in unloading and the contents got wet and were scattered about the store room. The government inspectors found that at ordinary temperature phosphoretted hydrogen was slowly formed from the ferrosilicon in such quantity that 195 grams would be given off by 10,000 kilograms. The presence of 0.25 part of PH_3 in 1,000 of air is said to be fatal. No arsenic was found.

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CHAPTER 22

CAUSTICS, AMMONIA, CHROMATES

CAUSTICS

THE caustics encountered in industry are: the inorganic acids, hydrochloric, nitric, sulphuric and hydrofluoric; the alkalies, sodium and potassium hydrate and their basic carbonates; quicklime, CaO ; sodamid, NaNH_2 (which changes, on a sweating skin, to NaHO); soda ash, and monochloroacetic acid. The most troublesome are the "caustic alkalies," the hydrates of sodium and potassium. Their effect is due to the solvent action on albumin, the saponifying power when mixed with fatty matter, and the avidity with which they take up water from the tissues (1).

Caustic burns of the skin are painful and slow to heal, caustic droplets or dust in the eye may cause blindness. The latter is the accident most feared in industrial processes which require the use of these chemicals. Sigrist (2) who had seen a case of cloudiness of the cornea with iridocyclitis, caused by hot caustic soda solution, experimented with concentrated alkalies and acids on the eyes of rabbits and found that alkalies, when they reach the conjunctival sac even in small quantity, are capable of diffusion through the cornea and may cause severe injury to the iris and ciliary body. The only way to prevent such an effect is to wash out the eye thoroughly within five minutes of the entrance of the alkali. Ammonia can be demonstrated in the anterior chamber within five seconds after introduction into the conjunctival sac and if the anterior chamber is punctured the danger of damage to the interior is lessened. The effect of acids is less severe, more superficial, for a thick crust forms at once and prevents the further penetration of the acid.

Accidents occur often in opening and emptying the metal containers of caustic alkalies and it is well to have these so made that the sides are straight and the lid as wide as the diameter of the container, so that the whole contents can slip out easily and completely without rolling and banging, although in cold weather a preliminary heating of the surface may be needed to melt the outer layer of the mass. The workman should never stand near enough to the caustic tub to receive a splash as the mass slides in, either there should be a chute down which the caustic can slide or the water

should be added after, not before. An abundant supply of wash water should be near at hand and a bubbling drinking fountain where he can wash out his eye immediately in case of accident. For ordinary protection of caustic workers the National Safety Council recommends a muslin mask with goggles, to prevent caustic dust dissolving in the sweat which collects along the edge of ordinary goggles. A cap will not do, because of the pressure on the forehead which also causes sweating. The same objection applies to the ordinary respirator, which allows dust to collect along the edges and also never fits closely under the eyes letting puffs of dust enter and settle there.

Monochloroacetic acid is used in only one process which I have seen personally, in one of the methods of making synthetic indigo. It is said to produce burns which are singularly painless but which are followed by extensive desquamation, sometimes the whole skin over the palm of the hand coming off in one sheet.*

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AMMONIA H_4N

Industrial poisoning from ammonia is always accidental, the result of a sudden escape of ammonia in gaseous or liquid form, usually from an artificial ice apparatus. I have the history of an engineer who was working in an ice plant, repairing the engine, when a valve stem blew out and the place was at once filled with ammonia vapors so strong that he was overcome and hurried to a hospital unconscious. His mouth and fauces were red and with a glazed appearance, his tongue dry and his breath distinctly ammoniacal. He was continually belching, but his lungs were clear and he recovered the following day and was discharged. In severer cases, edema of the lungs is likely to develop and the case follows the same course as that of poisoning by caustic acids.

Fairbrother (1) of East St. Louis described an accident which resulted in the poisoning of four men by fumes of ammonia. They were constructing an ice machine in a brewery and a large vat broke allowing liquid ammonia to spread over the floor, filling the room with its vapor. It was about three minutes before the men could be released and then one of them was found comatose, with a heart beat scarcely perceptible and he died in 15 minutes. His body was drenched in ammonia and his face and hands already blistered and tongue and pharynx denuded of mucous membrane. The second was in a condition very much like that of chloroform excitement,

* The same effect follows a burn with glacial acetic acid.

unable to stand, in wild delirium, with marked disturbance of heart beat and respiration. He was given morphin but died in two hours. The third was conscious and could walk alone. He was put to bed, complaining of occasional difficulty in breathing and preferring to lie propped up on pillows, but he could swallow easily and talk. About five hours later his dyspnea suddenly increased and after a few gasping breaths he died.

The fourth had suffered a compound fracture in the accident and sloughing necessitated amputation. At the time of writing, three months later, he was convalescing but all that time he had suffered from bronchial irritation with continual coughing, frequent hemoptysis, and partial paralysis of the right side. The cause of death in the three other cases was given as: "Heart failure, resulting from bronchial congestion, which was caused by inhalation of ammonia gas."

Ronzani (2) tested ammonia vapors in the same way as he had tested hydrofluoric acid. He found that long inhalation of as little as 0.1 per 1,000 parts of air does no harm, but if the proportion is raised to as much as 0.5 per 1,000, there may be a loss of agglutinins and bactericidal substances in the blood, after prolonged inhalation. Lehmann could tolerate 0.33 per 1,000 and he thought 0.5 per 1,000 below the danger limit, but Ronzani dissents, so far as long continued exposure is concerned. He finds at 0.5 per 1,000, more or less marked disturbance of general nutrition, irritation of the respiratory passages, changes in the blood, anemia, and a loss of resistance to infection by the anthrax bacillus, by the tubercle bacillus and by the diplococcus of Frankel. Lehmann found that dogs could increase their tolerance to ammonia fumes to five times as much as they had stood in the beginning.

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CHROMATES

The lesions caused by the chromates have had an amount of attention devoted to them which is quite out of proportion to their real importance, for they are not very painful and do little if any lasting damage. But, as in phosphorus poisoning, the lesions develop in places where they are easily detected and therefore from early days they have attracted the attention of physicians. In 1827 Cumming of Glasgow (1) wrote about "chrome holes," ulcers which develop in bichromate workers and are chiefly situated on the hands and arms. Papules appear first, then change to pustules

and finally to deep and penetrating ulcers or "sloughs." The skin must first be injured. The ulcer is characteristically sluggish, the edges indurated markedly and undermined, clear-cut, looking as if punched out, hence the name "chrome hole." The center has a scab resting on the slough and the floor under this is gray. A very common site for this ulcerative process is on the septum of the nose; other situations are the roots of the fingernails, the knuckles, the eyelids. Ulcers may form also on the edge of the nostrils, on the toes if the shoes become soaked with chrome water, and, rarely, in the throat. The effect is slow, gradual and not very painful.

Bécourt and Chevallier in 1851, (2) apparently without any knowledge of Cumming's paper, noted what was to them a new disease of the skin, occurring in some chrome works near Paris. They wrote to physicians in other countries asking if such things had ever been seen elsewhere and received an answer from Isaac Tyson of Baltimore in 1852, confirming their observations and saying that the Maryland workmen protected themselves by tying a wet sponge over nose and mouth. Ducatel (3), of the University of Maryland, added details as to the character of chrome ulcers and said that Baer of Baltimore had seen 20 cases, caused by chrome steam, which healed only when the work was given up. A little later, in 1869, Delpech (4) showed that not only the bichromates but the chromates could cause ulceration and that the ulcers might have their seat on the conjunctiva. Bronchial catarrh was also noted by Delpech but as a rarer symptom.

Wutzdorff (3) says that similar lesions were found in 1889 by the German factory inspectors among workers in the newly opened chromate works in Griesheim. A good deal of attention was directed to the subject during the military maneuvers in 1894 when 84 men in Anhalt who were called to the colors were found to be unfitted for service because of chrome ulcers. Leymann examined 722 workmen who were in contact with chromates and found ulcers and perforation of the septum in 253, or 35 per 100; respiratory disease in 8.8 per 100; and digestive disorders in 12.3.

In 1911, K. B. Lehmann and R. Fischer made a thorough study of the use of chromates in German industry (6). They found these compounds to be comparatively harmless. The form of poisoning which occurs is local only, any systemic symptoms are extremely rare. Even the local lesions are not now either frequent or severe. Fischer found that sickness with loss of time affected only 8.5 per cent of the force per year. Perforation of the septum is common but not disabling. The chief factor in the latter is the direction of the current of air which strikes a spot on the septum and deposits the chromate particles there. It is the only part of the septum not covered with squamous epithelium and this, with the poorer blood supply, make it less resistant.

In England Legge (7) found perforation of the septum in 71.6 per cent of 176 workmen and ulceration without perforation in 11.3 per cent. Some men seem to be immune while others develop ulcers after seven weeks (one case) or two to three months (two cases). More recently Mitchell (8) has presented figures which show a great improvement in English chrome works, for an examination carried out during three years and covering 846 men revealed only 175 cases of chrome sores, or 20 per cent. Mitchell believes that healing can be brought about in three weeks under proper treatment.

The latest article on chromate poisoning comes from Italy. Ranelletti (9) describes cases among workers in a chemical plant where large quantities of potassium bichromate were used. Among 69 operatives he saw 38 with ulceration of the nasal septum, six of them having complete perforation. There is first an area of hyperemia, then a yellowish gray spot appears and here excavation begins into the mucosa and finally through the cartilage, the opening being round or oval, smooth, and whitish yellow. There is never any attempt at repair, no hyperemic reaction, the loss of tissue is permanent. The process is painless and the victim is often unaware that he has a perforated septum, although a catarrhal rhinitis may precede it. Such a rhinitis usually comes on after a month or two of exposure and in a few more weeks ulceration sets in.

The use of the chromates as mordants in dyeing has given rise to the most widespread and notorious trouble from ulceration. Closely allied to this trade is the fulling of cloth. Woven cloth is passed through hot water with soap and soda to rid it of grease and cleanse and shrink it. In 1903 the German Factory Inspection reports tell of a very troublesome skin affection which was prevalent among fullers, an itching, papular or pustular eruption on the hands and arms and other exposed parts of the skin. It was traced to the chrome mordant which had been used in dyeing the cloth and which when in contact with skin already macerated by long soaking in hot alkaline water, was sufficient to cause the irritation leading to pustule formation. Among 202 fullers in Först, 35 persons were affected. Usually the course of the disease was mild and only in eight cases was it necessary to give up the work of fulling altogether.

Another use for chromates, very extensive in the United States, is the quick process of tanning. In the manufacture of colors, lead chromate is made from potassium bichromate and lead acetate, and alizarin colors are made by oxidizing anthracene to anthraquinone by means of this same agent. Chromates are used in the carbon process in photography and in paste form on copper plates in photo-engraving. A large plant in which bleaching and dyeing are done uses for these purposes the following chemicals: soda ash, acetic acid, bichromate of soda, tannic acid, and antimony salt. Ram-bousek found several records in 1907 and 1908 of perforation of

the septum in makers of Bohemian glass. Among 300 chrome tanners, he says, 19 cases developed in one year's time. Another occupation which is said to involve this danger is the making of Swedish matches.

There is very little in the literature about systemic poisoning from the chromates. Leymann believes that such does occur and describes a case of nephritis in a man who inhaled much chromate dust. Gilman Thompson discusses the subject and describes some instances from his own practice. On the other hand Lehmann fed animals for months doses far larger than any workman could ingest, and there was absolutely no effect to be found on kidneys or on lungs.

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CHAPTER 23

SULPHURIC ACID. HYDROCHLORIC ACID. PHOSGENE

SULPHURIC ACID

SULPHURIC acid must be considered together with its anhydrids, sulphur dioxid and trioxid; for they are encountered in industry at the same point. SO_2 is given off when sulphur is burned with air supply, and in moist air it quickly changes to H_2SO_3 , which readily dissolves in water, making H_2SO_4 . This happens when it reaches the moist mucous membranes of nose, mouth and throat; and so it produces the well-known caustic effect of sulphuric acid. SO_3 is not encountered in industry except from oleum, or fuming sulphuric acid, which is H_2SO_4 holding SO_3 in solution. One cannot produce SO_3 by roasting sulphur; it is necessary to take the SO_2 and oxidize it to SO_3 , which is done by the different methods for making sulphuric acid.

According to Kobert (1), the effects of H_2SO_4 and SO_2 are partly reflex, partly dependent on the acidifying and destructive action on the blood. Ogata and Lehmann (2) tested human beings and found that irritation from fumes of SO_2 begins at as low a point as 0.01 part in 1,000 parts of air, and that susceptible people are rendered ill by 0.03 part, but tolerance is quickly established. Animals are killed in ten minutes by 0.8 part, with dyspnea, cyanosis, convulsions, catarrhal or croupous inflammation of the respiratory tract. In human beings, chronic catarrh may be set up, but usually men can come to tolerate a large quantity with apparently no injury. It is possible to accustom animals to the fumes. Thus, Tidy (3) succeeded in habituating mice to the effects until they were able to endure an atmosphere in which 10 grains of sulphur had been burnt, while at the beginning they had suffered from the burning of as little as half a grain, and Lehmann (4) found that men who were accustomed to the fumes did not suffer more severely in an atmosphere of 0.03 or 0.04 part per 1,000 of air than did unaccustomed persons in one of 0.01 per 1,000.

The symptoms are at first those of suffocation, the glottis closing to shut out the fumes; then the irritating caustic effect of the acid which forms on the moist surfaces of the mucous membranes. From my own experience in phenol plants during the war I should call SO_2 the most painful of the industrial gases, producing almost

immediately a feeling as if a red hot stream had been poured down the throat. If the exposure is prolonged, if the man cannot at once escape to pure air, vomiting will occur, and the vomit may be blood-streaked. A very severe exposure is followed by the expectoration of bloody sputum. The symptoms disappear, however, with surprising quickness in the fresh air, although a raw feeling in the throat may persist for some hours.

Von Jaksch (5) says that symptoms are mostly confined to the respiratory tract. There is a violent strangling cough with expectoration of blood-stained mucus, and if exposure is longer, cyanosis, croupous inflammation of bronchi, and lobular pneumonia.

In death from SO_2 fumes the post-mortem appearances are those of asphyxia.* The blood is very dark and has in part an acid reaction. The hemoglobin is changed first through loss of oxygen, then by decomposition, to hematin, as in poisoning with mineral acids. The respiratory tract is catarrhal or even croupous in aspect, due to the action of the acid. The lungs are partly edematous.

Reports of fatal poisoning in industry are rare. Péron (6) reports a case of a young man who, having gone into a place where sulphur was being burned, was so suffocated that he had difficulty in getting out. He was able to return to work the same night, however, but later was seized with repeated chills and eventually died, twenty days after the exposure. Autopsy showed necrosis of the respiratory passages, purulent pericarditis, and suppurative adenitis.

A case was reported by T. F. Harrington, former Medical Commissioner of Labor of Massachusetts, which was unfortunately not worked out in detail, but apparently the only caustic poison to which the victim could have been exposed was SO_2 . The man, 42 years old, had been employed for six months in the sodium bisulphate department of a chemical works as night foreman. One morning he left at the usual time, half past six, and then in the afternoon of the same day was suddenly attacked by a violent cough, dyspnea, and suffocation, and died in half an hour. Autopsy showed cyanosis, marked irritation of the respiratory tract, edema of the lungs, congestion of the liver, spleen, and kidneys. This delayed appearance of pulmonary irritation is characteristic of all the caustic acids when inhaled.

It is improbable that much harm is done by acute poisoning; for the gas is too irritating to permit it. The important question is whether prolonged exposure ultimately affects the workmen by setting up chronic laryngitis, bronchitis, gastritis. There appear to be no reliable data on this point. Von Jaksch assumes that chronic catarrh may be set up, and W. Gilman Thompson (7) has seen bronchitis, conjunctivitis, and gastric catarrh in men exposed for a long

* Doremus and McNally in *Legal Medicine and Toxicology*, by Peterson, Haines, and Webster, Phil., 1923, vol. II, p. 341.

time to SO_2 . Pedley (8) examined 17 men who had been exposed in paper pulp works to sulphur dioxide. Seven of them were exposed for one year, the others between one and eight years. Only one, a man 41 years old, who had been employed for six years, complained of stomach trouble. Two men had moist râles in the lungs; one of them, a man 42 years old, had been employed for six years; the other, 21 years old, for one year. Emphysema was found in the lungs of a man of 48 employed for one year; and dry râles, in a man of 45, employed for six years. No other findings of significance were noted and the only possible conclusion is that many men can work in these fumes without demonstrable harm. Of course, those who find themselves seriously affected by the fumes quickly leave the job, so that the susceptibles are eliminated. Sulphur trioxide was tested during the war for its possible use as a poison gas, but it was found to be not poisonous, but irrespirable. The effect was to strangle the man; he did not breathe it in at all, but drove it out again without change. It does not dissolve in water and therefore cannot injure tissue.

Making Sulphuric Acid.—Sulphuric acid is made by two processes, the older "lead-chamber" process and the newer contact process. For both, pyrites is roasted to produce sulphur dioxide, or sulphur flowers are burned, the latter being generally used in connection with the contact process. Pyrites roasting is hot and disagreeable work, but in the newer plants it has been made as tolerable as possible by good ventilation. One danger comes from the volatilization of arsenic, which is present as an impurity in all these ores, and which passes over with the sulphur oxides and must be removed in the "dust box," together with unburned pyrites and oxides of zinc and antimony. In the burning of sulphur flowers there may be neither excessive heat nor any disagreeable fumes, especially if a revolving furnace, automatically fed, is used.

In either process the sulphur dioxide must be converted into sulphur trioxide in order to form sulphuric acid. In the lead-chamber process this is accomplished by the oxidizing action of oxides of nitrogen, which are introduced, together with steam, into the so-called "lead chamber." The hot sulphur dioxide gases, with FeO and soot from the burners, pass first through a tower called the Glover tower, over which sulphuric acid containing nitrogen oxides is circulated. The hot gases drive out the nitrogen oxides and also partially concentrate the sulphuric acid in the Glover tower, being thereby themselves cooled in the process. The mixture of sulphur dioxide and nitrogen oxides passes then to the lead chambers, where the oxidation takes place as above described, additional quantities of nitrogen oxides being supplied directly to the lead chamber. The gases leaving the lead chamber are passed through a final scrubbing tower or series of towers known as Gay-Lussac towers, where the valuable nitrogen

oxids are removed by scrubbing with sulphuric acid before the gases are finally allowed to escape to the air.

It is in the chamber process that the escape of fumes of sulphur dioxide may be great enough to cause much discomfort and even actual harm. In some acid works the Cottrell process for condensing these fumes by electricity has been installed, apparently with excellent results.

The Contact Process depends on the fact that if pure gaseous SO_2 and a proper proportion of oxygen are treated in intimate contact with a catalyst—platinum or ferric oxid—more or less complete and rapid oxidation of SO_2 to SO_3 takes place. Then SO_3 is recovered, cooled, and passed into weak sulphuric acid. The contact material is usually finely divided platinum or platinized asbestos and the gas from this converter or oxidizer is “scrubbed” with weak acid. The process results in the production of strong acid directly by absorption of the trioxid in sulphuric acid, and it is possible also to produce sulphuric acid containing free SO_3 in solution, known in industry as oleum or fuming sulphuric acid.

Perhaps the greatest risk in connection with the production of sulphuric acid comes from the arsenic and selenium, almost always present as impurities in the ores which are roasted for chamber acid. The Bureau of Mines tells us that in many chamber-process plants, ores containing as much as one per cent of As and Se are utilized. However, if too much arsenic is present it will tend to clog the flues and towers and the acid will corrode the chambers.

For the contact process, anything over 0.2 per cent is too much; because the necessary cleaning of the contact mass would be too elaborate, and therefore ores with a higher percentage than that are not used in contact production. If the contact mass does become “poisoned” with arsenic it must be taken out and treated with dilute nitric and hydrochloric acids, with vigorous stirring and gentle heat, during which there is, of course, great danger of producing hydrogen arsenid or hydrogen selenid gas. Arsenic collects chiefly in the Glover towers where it forms crystals and sometimes these form even in the cooling acid from the towers. It is not all caught in the tower but some passes on into the chambers and has an injurious effect on the lead linings. Selenium turns the acid a reddish color, but it is not so abundant as arsenic. It can be removed by hydrogen sulphid and the excess of the latter can be taken up by a solution of caustic soda, or by milk of lime, or, rarely, it is precipitated as barium sulphid.

Sulphuric acid has many uses in modern industry; indeed the industrial development of a country can be gauged by the amount of sulphuric acid it consumes. At the time the armistice was signed the manufacturing capacity of the United States was 9,600,000

tons of 50° Bé.* Twenty-nine per cent was made in contact plants, 71 per cent in chamber plants.†

The dilute acid up to 60° Bé. is used for the production of sulphates, of hydrochloric and nitric acids, boric and chromic acids, also organic acids; for pickling metal to be tinned or galvanized; for producing copper, zinc, nickel, gold, and silver; for making ether; for forming storage battery plates; for electroplating; for making and purifying organic colors; for making starch, syrup, and sugar. Stronger acid is used for purifying benzene, petroleum, paraffin, and other mineral oils; for making nitroglycerin and pyroxylin; picric acid and fatty acids. Fuming H_2SO_4 , oleum, is used to fortify weaker acid and also in the mixed acid used in making explosives. The largest uses in the United States are: (1) making phosphate fertilizer, (2) refining petroleum products, (3) pickling iron and steel, (4) making nitrocellulose, celluloid, and nitroglycerin, and (5) in general chemical and metallurgical processes.

In the making of explosives and of celluloid, sulphuric acid is added to the nitric used in nitrating in order to take up the water that is liberated and to keep the nitric acid from dilution. I found three cases of severe bronchitis with temperatures of 102 to 103° in a hospital near a picric acid plant where the men had breathed fumes of H_2SO_4 . Another case, also connected with the manufacture of explosives, was fatal, death following in less than 24 hours the inhalation of a large quantity of acid.

The manufacture of paper involves the formation of fumes of SO_2 during the process of digestion of the chipped wood by the sulphite process. The sulphite is formed by the reaction of sulphur dioxid from burning sulphur, or limestone, or dolomite, and water. Usually this is done in an acid tower with cylinders filled with limestone, a stream of sulphur dioxid entering at the bottom and meeting a trickle of water sent in at the top. The sulphurous acid then forms calcium sulphite. By another method sulphur dioxid is passed through milk of lime. It is rare that fumes are heavy enough to cause harm, but men are said to have been suffocated by sulphur dioxid from a sulphur burner. The sulphite liquor and chips of wood fill the digester which is then covered and steam is turned on until the pressure reaches about 70 pounds to the square

* Since the specific gravity of the acid can be determined more easily than its strength, Baumé's hydrometer is used for all dilutions of H_2SO_4 weaker than 93.19 per cent, and the strength given in degrees Bé., thus:

Per cent H_2SO_4	Degrees Bé.
62.18	50
77.67	60
93.19	66 (This is "oil of vitriol")

100 per cent is called monohydrate, and with SO_3 dissolved in it, it constitutes fuming acid or oleum.

† A. E. Wells and D. E. Fogg, *Bureau of Mines Bull.*, 184, 1920.

inch. The "cook" continues for eight hours, at the end of which time the digester is "blown" by opening a valve at the bottom and allowing the contents to be forced by the pressure inside into a large tank called the blow-pit. Unless special precautions are taken, fumes of sulphur dioxid become very strong about the blow-pit, almost unbearable to the uninitiated; a sense of suffocation is felt, there is a violent desire to cough, and the eyes smart. Vomiting of blood and bloody expectoration are said to occur sometimes among the men employed here. On the charging floor, also, when the cover of the digester is removed after it has been blown, fumes may be very strong and even seasoned men show signs of discomfort. It is particularly important to remove the fumes from the charging floor; for it is here that most of the men in this department work. This can fairly easily be done by providing a movable exhaust stack connected with a fan, placing the stack over the mouth of the digester when the cover is removed.

The absolute number of men engaged in sulphur burning and tending digestors is very small, the United States Census of 1910 giving only 235 acid makers and 187 "cooks."

In the sulphur burning department, if the construction or operation is faulty, the men work constantly in fumes of varying intensity. The digester-house men are exposed only intermittently, but usually to much more concentrated fumes.*

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CHLORIN AND HYDROCHLORIC ACID

Lehmann (1) whose studies on poisonous gases were the basis for the selection of gases for trench warfare by the Germans, established the danger point for chlorin gas at 0.01 per 1000 parts of air. At this dilution it is injurious, at 0.1 per 1,000, if inhaled for an hour or two, it may cause death. He was, however, able to accustom

* This description is taken from the thesis of F. J. Pedley, submitted for the degree of Doctor of Public Health, Harvard School of Public Health, 1923.

dogs to chlorin so that at the end of a month they could inhale ten times as much as at the beginning.

Winternitz (2) of the Chemical Warfare Service tested chlorin gas on 326 dogs, 175 of which died within 24 hours; 46 from 2 to 5 days after gassing; 26 in 5 to 12 days after and 79 survived as chronic or recovered cases and were killed and examined at intervals of 15 to 193 days after gassing. The findings in the first group were: sloughing of the mucosa of the upper air passages and membranous inflammation of trachea and bronchi; areas of atelectasis and of emphysema in the lungs; extreme congestion and edema of the entire respiratory tract and a pneumonia developing in a few hours. In the next two groups the most striking feature was pneumonia, sometimes complicated with gangrene and abscess formation, and, in those that lived longest, a tendency to the formation of solid areas in the lungs. In the last group, probably the one most interesting to the industrial toxicologist, the infection which followed gassing sometimes resulted in a bronchitis, with dilatation of the bronchi, then thickening of the bronchial walls and finally a closing of some of the smaller bronchi (bronchiolitis obliterans). At the same time there was often an organizing pneumonia and the bronchial lesions were followed by atelectasis and emphysema.

During the war it was also noted that in some soldiers gassed with chlorin there was a marked caustic effect on the esophagus and stomach, as well as in the air passages. The men suffered from regurgitation of bitter, burning fluid, cramps and diarrhea, and they vomited blood (3) (4).

As for the lasting effects of such gassing, the experiments of Winternitz just described show that a permanent damage to the lungs may be left by a severe dose of chlorin fumes. Leymann (5) says that exposure to small quantities day by day results in irritative lesions of the air passages. In a model plant in Germany, making bleaching powder, he found that 17.8 per cent of the men exposed to chlorin gas suffered from respiratory disease, as compared with 8.8 per cent of the men in other departments. Most of the former were in the chlorid of lime department. English factory inspectors believe that workers habitually exposed to the fumes of chlorin in minute quantities suffer from decay of the teeth and possibly from chronic cough (6). I have found that in American plants the optimistic belief is generally held that these fumes are actually beneficial, that men with incipient colds are cured if they go into the chlorid of lime department to inhale the gas, and that during the great influenza epidemic the chlorid of lime men suffered far less than other men. None of these impressions have been confirmed by careful observations nor has there been any attempt to really collect evidence in industrial plants as to the beneficial action of chlorin gas in minute quantities, but the unanimity of opinion commands respect.

Chlorin gas is produced now chiefly by the electrolytic process, from common salt, is passed into containers and sold to the trade. In the largest plant which produces it in this country it is used also for the production of chlorid of lime, by sending the gas into small chambers the floor of which is covered with a thick layer of powdered lime. In shovelling out the finished product and in packing it, a good deal of the loosely combined chlorin is released and the men who do this work are now provided with army gas masks. The method used in a large German plant is better. The floor of the chlorinating chamber slopes to the center where there is an opening into a hopper, and when the process is over it is only necessary to open the hopper, from outside the room, the chlorid of lime falls into the hopper and can then be carried further by gravity down a chute to a mechanical barrel packer and the workman never is exposed to fumes at all.

Chlorin is given off in the early stages of nitric acid production, when the sulphuric acid reaches the sodium nitrate, for there is always some common salt mixed with the latter and this is first attacked. The fact is well known in acid works and experienced hands avoid the danger. Newsprint paper, cardboard and wrapping paper, which make up from 60 to 70 per cent of American paper, are made from unbleached stock, but finer paper stock must be bleached. Practically the only chemical used in bleaching is chlorin, either pure, brought to the mill in large cylinders, or produced in the mill by electrolysis, or in the form of bleaching powder. The odor of chlorin is fairly strong in the neighborhood of the concrete or tile bleaching tubs, but poisoning occurs only from some accident, such as the breaking of a chlorin container or the unsuspected leaking of a container with the gas spreading into a workroom. Such an accident occurred in a Pennsylvania plant recently, affecting several men but without fatal result. In view of this possibility, paper pulp plants should always have gas masks easily accessible, and it should be a rule not to send a man alone into the room where the chlorin cylinders are stored, for fear a slow leak has allowed a dangerous amount of gas to escape.

A recent factory inspection report from Bavaria tells of several cases of poisoning from chlorin gas. Six carpenters were at work in a factory, apparently making alterations which resulted in the escape of this gas and because they did not know what had happened they did not get away quickly enough, not till they had inhaled enough to cause serious respiratory disturbances, but without fatal results. A much more unusual case was that of a man who was in charge of an apparatus in which chlorin gas was generated and who for a few minutes breathed some of the escaping gas. Apparently he was not affected by it for he did not leave his post, and it was not till two days later that he declared himself ill, but in five days

more he was dead. One factory reported 13 cases of chlorin bronchitis and four very severe cases of illness, one of them ending in death.

The action of hydrochloric acid differs from that of chlorin in that it attacks the upper air passages and there is an involuntary resistance to the inhalation of so caustic and painful a vapor, unless it is much diluted, and it is detected by the odor well on the safe side of danger. Leymann's (5) experiments showed that 2 to 5 parts per 1000 of air produced clouding of the cornea and after an hour violent inflammation of the lining of nose and throat and congestion and hemorrhages in the lungs. Lehmann (7) says man can tolerate from 0.1 to 0.2 part per 1,000, something more than that produces bronchial catarrh.

Hydrochloric acid fumes are given off in the production of the acid from common salt and sulphuric acid, and in pickling metal, as for instance steel wire. The wire is passed first through annealing baths of molten lead, then air-cooled, and then into a succession of HCl baths. Coming out, a shower of cold water washes off the acid. When the wire passes into the acid a copious evolution of hydrogen results and tiny bubbles of it tend to follow along as the wire is drawn through and to come out with it. Each is coated with an acid film and, being light, it rises into the air carrying the acid with it.

Both chlorin and hydrochloric acid fumes are given off in certain processes of dye manufacture, such as the making of anilin hydrochlorid, and the manufacture of indulin and nigrosin by melting together anilin, nitrobenzene, ferric chlorid and hydrochloric acid. I have the history of a man who was overcome by chlorin fumes in a dye works, was unconscious for two hours, but recovered completely without inflammation of the air passages. The German Factory Inspection report for the Bavarian district gives the history of a man who died of the irritating effect of hydrochloric acid vapors which he had breathed three days before.

Chloracne, an irritating dermatitis, has been very prevalent in German works where chlorin is recovered by electrolysis. It is now generally held to be due to the action of chlorinated tar products, and Rambousek says that it was completely done away with in one place when the carbon anode was replaced by one of magnetite.

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PHOSGENE COCl

This gas, so famous in trench warfare during the latter part of the World War, is of very restricted use in industry, yet it has given rise to fatal accidents in chemical works producing dye intermediates, for it is a necessary step in the production of an important one, Michler's ketone. It owes its poisonous action to the fact that it decomposes readily in the presence of water to hydrochloric acid and carbon dioxid. This decomposition takes place within the body when the gas reaches the finer bronchioles and the alveoli of the lungs, and is acted on by the watery vapor there. The effect of phosgene thus differs from the effect of hydrochloric acid, in that it is not immediately irritating, and therefore while the latter attacks the upper air passages and produces violent inflammation of the larynx, trachea, and bronchi, phosgene does not produce its effect till it has penetrated deeply into the lungs, and because it does not produce any local irritation the victim has no warning of the fact that he is breathing a deadly gas.

Winternitz, Wislocki and Finney (1) summarize the effect of experimental phosgene poisoning, as observed by the Chemical Warfare Service, as follows: The results in dogs vary according to the length of time the animal survives gassing. At first there is a severe pulmonary edema with extreme congestion, which reaches a maximum toward the end of the first 24 hours, and then disappears gradually in animals which live as long as ten days. With the edema there is a fibrinous exudate, especially around the finer bronchioles and a typical lobular or pseudolobular pneumonia is the result, which is often complicated by necrosis in the wall of the bronchus and abscess formation. In case of healing, areas of obliterative bronchiolitis and organizing pneumonia result, and these may remain as chronic foci of infection.

The experimental work done in France by Achard, Lebac and Binet (2) was carried out on dogs and rabbits. During the stage of acute edema of the lungs the authors found a pronounced increase of red blood cells, an increase of hemoglobin and of the respiratory capacity of the blood, which is a reaction of the organism against asphyxia. At the same time there is a leucocytosis, polynuclear, which may be found also on the following day after gassing. The week following the experiment, there are often found increased coagulation of the blood and slight diminution of the albumins of the serum. After the disappearance of the acute symptoms there is a progressive diminution in the red cells, in the hemoglobin and

in the respiratory capacity, in other words a progressive anemia which seems to be of a toxic nature. The return to the normal state is slow in proportion as the poisoning was intense.

Apparently the first cases of industrial poisoning from phosgene occurred in 1905 (Rambousek (3)) in a German chemical works. There was a leaking valve, and the workman who was sent to repair it was given an air helmet to wear, but took it off because the glasses became clouded. The foreman then called him out and put on the helmet and made the repair himself. Later on this same workman carried a sack of salt into the room where the gas had leaked, covering his face with a cloth soaked in alcohol. About an hour and a half later he began to feel ill, and he died the following morning. Three more cases, not fatal, are described by Rambousek, men who suffered from severe bronchitis with difficult breathing and weak heart. In one, the sensitiveness of the air passages lasted a long time.

There were several cases of fatal poisoning from phosgene in American industry in the years 1914 to 1918, but no one can say how many, for a great deal of secrecy was observed with regard to them and it was impossible to obtain positive information about the rumors which arose from time to time during those years. The workmen did not know what gas they were producing, since it was called by some fictitious name, such as "Hackensack gas" in one large factory. The New Jersey State Department of Labor told me of three fatalities, all of which occurred in dye works, although one of them should really be attributed to the gas warfare industry rather than to the dye industry because the plant was at the time engaged in war work. This last instance is worthy of special mention because it shows how extensive is the danger of an accident which allows phosgene gas to escape in the vicinity of the working force.

In a plant which was manufacturing phosgene for use in the war something went wrong and a quantity of gas escaped at a moment when about 180 men were in the vicinity and they are supposed to have breathed more or less of the fumes. They were all put under medical treatment at once, and 20 developed symptoms, fairly serious in some cases, but not fatal. An Italian teamster, who is said to have been more than 1,000 yards away, was not thought to have been exposed and was allowed to go on with his work. He went home at the end of the day and complained of breathlessness. A doctor who was summoned said he was developing pneumonia, but by five o'clock in the morning he was dead, and the case was pronounced to be one of phosgene poisoning. One of the physicians in charge of the other men said that they suffered from intense headache which lasted about 72 hours, exhaustion, and a weak heart, and a strangling, exhausting cough without sputum. One man, a Negro, developed edema of the lungs but recovered.

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CHAPTER 24

NITRIC ACID. HYDROFLUORIC ACID

NITRIC ACID

NITRIC acid must be treated together with its anhydrides, the oxids of nitrogen (which are usually known in industry as nitrous fumes), for the gases given off when strong nitric acid is exposed to the air, or when nitric acid comes in contact with any organic matter, consist of a mixture of oxids. The ordinary way for accidental poisoning from nitric acid to occur in industry is through a leak in the apparatus in a nitrating or nitric acid plant. When the contents flow out or spurt out there is an escape of nitrogen oxids, at first whitish yellow to yellow, and then through all the shades of orange to dark orange brown, and mixed with them there may be a fine spray of the acid.

Haldane (1) found that exposure to 0.5 per 1,000 of nitrogen oxid fumes for half an hour was enough to kill mice, but death did not occur until after about twenty-four hours.

The effect of the fumes is locally caustic, causing congestion and edema in the tissues exposed, and, according to some observers, this caustic action is enough to account for all the symptoms. Thus, Hudson (2) found that he could limit the action of the gas in the dog to one lung by clamping off the right bronchus, whereupon a typical pulmonary edema appeared in the left lung with a normal right lung. On the other hand Hiltman (3), experimenting on guinea pigs, found that if the animal were killed at once after only six minutes' exposure, there was evidence of absorption of the poison without any caustic action. There was a general congestion of the lungs and emphysema, while the lining epithelium of the alveoli was intact. Even in an animal dying three and a half hours after exposure, the alveolar cells were unchanged, while the lung showed areas of emphysema and atelectasis and the framework was swollen and soaked with yellow fluid. All the abdominal organs were congested.

As far back as 1868, Gamgee (4) showed that at least part of the action of nitric acid was to be explained by the vasomotor paralysis, which is a characteristic effect of the nitrites, and by the formation of methemoglobin. More recently, Loeschke (5) confirms these statements, as does also Zadek (6). Harnack (7) believes that the

poisonous action of nitric acid depends on its reduction to hydroxylamin and ammonia, which produce methemoglobin, and the essential feature of this form of intoxication is the presence of methemoglobin. It seems, however, that the nitric acid in the blood may sometimes act so rapidly on the lower centers as to leave no time for such decomposition to take place before death has occurred, for in a case which was examined by Apfelbach and McNally (8) of Chicago, nitric acid, but no methemoglobin, was found in the blood.

The immediate effect of inhaling the fumes is not very asphyxiating; indeed it is unfortunately not painful enough to give the victims sufficient warning of danger. Many workmen have stayed in the poisoned atmosphere long enough to cause damage to the throat or lungs, and yet at the time they did not realize that anything more serious was happening than a "choking" from the gas. Taking the purely local effects of the nitrous gases first, one finds occasionally inflammation of the mouth and nasal passages. A physician in one of the gun-cotton plants during the war told me of four cases of inflammation and ulceration of the mucous membrane of the mouth, another of a case of inflammation of the nares so severe as to force the man to give up work. There may be inflammation of the larynx severe enough to be alarming. Seven such cases were reported to me during the war, in two of which edema of the larynx developed. One of these men had inhaled rather concentrated fumes during the morning, but did not really begin to suffer from sore throat until evening. It was necessary to introduce a laryngeal tube to prevent suffocation.

Symptoms in the chest are far more frequent. There is at first a sensation of choking, a strangling spasmodic cough, an instinctive effort to get rid of the irritant. If the man follows his natural impulse and holds his breath as long as possible, then takes a deep gasping inspiration and holds his breath again, he may drive the fumes deep into his lungs and cause serious damage. There is a feeling of burning and smarting in the chest and the man says that he cannot breathe because his lungs are shrunk or "tied up in a knot," that he has nothing to breathe with. If he can get at once into the fresh air this bronchial spasm is usually quickly relieved by the ordinary first aid treatment, a few drops of chloroform in hot water with sometimes aromatic spirits of ammonia. Mild cases of so-called fume sickness were very frequent in explosive plants during the war, especially in summer. One carefully managed gun-cotton plant where records were kept had an average of 57 cases of nitrous fume poisoning in an average force of 600 men during each month from June to September.

An apparently mild case may, however, within a few hours turn to a very serious one, for the real damage done to the lungs does not appear at once, but usually from four to twelve hours later. A

bronchitis may develop, or a pneumonia which is said by Hudson (9) to be lobar, not lobular as one would expect. He says that it follows the usual course except that it is likely to be less severe, unless the man has a latent tuberculosis, when it may result in a lighting up of the infection. An instance of slow after-effects of gassing occurred in one of the large guncotton plants. A young man of twenty years was injured when an explosion of nitrous gases occurred in a nitrating shed and he could not escape, but had to be dragged out by fellow workmen through a window. Although he was exposed for some minutes to very heavy fumes, he recovered fairly promptly from the first effects. The next day he suffered nothing worse than a headache and did not develop a cough till the fourth day, when the symptoms in his lungs increased very rapidly. He died at the end of two weeks and the autopsy showed gangrene of the lungs.

Hall and Cooper (10) of Denver described a wholesale poisoning from nitrous fumes in a printing shop, and they were able to follow the subsequent histories of the victims, eighteen firemen and two printers. The fumes came from a broken carboy of nitric acid and the mistake was made of throwing on sawdust and using chemical fire extinguishers instead of drowning the acid in water. The fumes that developed were severe enough to affect twenty men, four of whom died. The immediate symptoms were dyspnea, pain in the stomach, pain in the chest, dryness of the throat, coughing, vomiting, dizziness, and difficulty in walking. Nearly all the men went back to their fire houses not thinking themselves seriously sick, but within 24 hours all but one were in the emergency hospital suffering with an exacerbation of the foregoing symptoms, prostration, fever, nausea and vomiting, voluminous expectoration (sometimes bloody), severe pleuritic pains, and extreme cyanosis. The autopsy performed on one of the victims who died on the day after the accident, showed the changes typical of rapid nitrous fume poisoning: a congested, edematous condition of the lungs, which were heavy and bled freely on section, and extremely dark blood. A second victim died, but not until a month after the accident, and in this case the autopsy showed broncho-pneumonia with almost complete solidification in some areas, which either had undergone coagulation necrosis, the alveoli being full of necrosed cells, or the beginning of a fibrous change. The blood was extremely dark and incompletely clotted.

Much the same sort of accident occurred in one of the Berlin suburbs Neuköln, and was described by Javels (11) in 1910. A fire broke out in a plant where there were large carboys of nitric acid and the wooden cases of these caught fire, the carboys broke, and the fumes of nitrogen oxids spread through the room. Eleven firemen were exposed to these fumes for about four hours, but all went home apparently in good condition, ate their supper, and went

to bed. At about two in the morning six of them woke suddenly with severe headache, vomiting and diarrhea, then dyspnea and tightness in the chest. The remaining five developed the same symptoms within a few hours so that all eleven were sent to the hospital the following day. Vomiting and diarrhea were continual there was a terrible thirst, polyuria, and all signs and symptoms of intense congestion of the lungs with edema, and fever ran to 104° F. The three most severely affected had albumin in the urine, but no casts, and one of them also gave the test for sugar and for nitric acid. Methemoglobin was demonstrated by spectroscopy in these three men, but only one died, and he after eighteen hours' coma. The blood was a deep brown and contained methemoglobin. The others all recovered completely, and when Javels examined them several months later they showed no after-effects.

Hall and Cooper (10) state that one-third of their cases suffered relapse, usually within three weeks of the accident, with symptoms resembling the original attack, but less intense, and lasting about a fortnight. Of the four fatal cases two did not die from the early effect of the fumes, but from pneumonia developing twenty-two days and thirty days later. Fränkel (12) has described the condition in the lungs of a man who breathed nitrous fumes, had the usual symptoms, and then, after a free interval of a fortnight, developed dyspnea, and died on the sixth day. No pneumonia was found at autopsy, but there was a closure of the lumen of the smaller bronchi with necrotic epithelium, under which was proliferating granulation tissue, a bronchiolitis obliterans. Hall and Cooper found also that the effect of the nitrous fumes might last for many months. Nine months after the accident, eleven of the sixteen surviving men had not regained their usual health but complained of shortness of breath, cough, pain in the chest and loins, gastrointestinal disturbance, and nervousness. Loss of weight was general, ranging from twenty-five to forty pounds.

The typical form in which severe and fatal nitrous-fume poisoning appears is not a pneumonia but a rapidly developing congestion of the lungs with edema. This comes on some hours after the man has inhaled the fumes. If part of the lung tissue is still undamaged, treatment by oxygen inhalations will pull the man through, but if he has breathed deeply of the gases he may die within a few hours. Usually such cases follow some accident which has released an unusual quantity of the poisonous gases. For instance, during the war, one man fell asleep in a nitrating shed of a gun-cotton plant and when a fire occurred he was not discovered and dragged out until he had breathed a good deal of the fumes, enough to kill him. Another accident took place during the war in a picric acid plant with very primitive equipment and excessively bad nitrous fumes. The victim was a gas fitter who was installing a fan to carry off the

fumes. To do this he had to stand on a platform just where the fumes struck him. He was overcome once and had to go out of doors to get his breath and he was advised to stop for the day and not to expose himself again, but instead he went back, was again "knocked out," and had to go home. He did not seem very ill, ate his supper, and went to bed and to sleep, but during the night he woke with a sense of strangling and when the doctor came he found him propped up in bed, his face purple, his eyes full of fear, unable to speak or move because he needed every particle of strength in the struggle for breath. At first his cough was dry, but then it began to bring up bloody froth, his dyspnea persisted, his whole body became livid, he lost consciousness gradually, and, after a convulsion, died at daybreak. An autopsy showed intense congestion of all the air tubes, down to the very finest, while the lungs were solid with exudate.

A rather unusual accident took place in a paint grinding factory. Chrome green was being made in an open chaser by mixing yellow chromate of lead and Prussian blue, ferrocyanid of potassium. An iron nail fell into the chaser and the friction caused sparks to form which ignited the contents of the chaser, and, as they burned, nitrous fumes formed from the decomposition of the cyanids. The head of the factory fire department was exposed to the fumes for several minutes putting out the fire, but he did not realize that they had had any harmful effect. He went home as usual, ate his dinner, and then woke about midnight with intense air hunger. He died at five in the morning from congestion and edema of the lungs. Sometimes these men complain of violent pain in the abdomen and there is vomiting and diarrhea, but usually, even if there is involvement of the intestinal tract, the symptoms in the lungs are so severe as to overshadow them.

There is a difference of opinion as to whether the susceptibility to nitrous-fume poisoning is different in different individuals, as is true of other industrial poisons. Some physicians maintain that there can be no difference in susceptibility to caustic fumes any more than to burning from fire, but there are certainly instances which seem to show a difference in the reaction of men to the same atmosphere. Czaplewski (13) describes an accident which resulted in the poisoning by nitrous fumes of eight men, of whom one died on the second day; one on the ninth; five were ill for a week; and one was back at work the day after the accident. I found several records similar to this during the war. A man in a picric acid plant developed congestion and edema of the lungs from which he very nearly died, after exposure to the fumes from a "boil over" which did not seriously affect any of the other workmen in the place. There was also a man who died after four hours' work on a night shift with some sixty men in the same nitrating shed. None of the

others suffered appreciably from the fumes that night, and yet an inspection of this shed showed that it would not have been possible for this one man to inhale much more gas than did the men working on each side of him.

Finally there is a less well recognized form of nitrogen-oxid fume poisoning which is so rapidly fatal that only slight anatomical changes are found after death. The poison in these cases seems to act directly on the respiratory center, and death occurs suddenly after very short exposure to fumes without sufficient damage to the lungs to account for it. Five instances were reported during the war of men who had worked only a short time in nitration, two of them less than one eight-hour shift, and who had been suddenly overcome and died before medical care could be given. One of them was a Negro who was found dead in his bunk the morning after he had worked in the nitrating shed of a very bad picric-acid works. He had certainly not suffered from dyspnea during the night; for he slept in the same room with many other men, in a company barracks, and they would have heard him call for help. The physician who reported this case was not present at the autopsy, but the coroner described the findings to him and consulted him as to what to put on the certificate. There was some hyperemia of the brain, meninges, and lungs, but it was not excessive anywhere. The heart showed nothing, but the blood was dark and fluid. They agreed to call it "heat prostration," since they had found no changes sufficient to cause death. After telling of this case the physician went on to describe to me two other obscure cases of sudden death in men working in the same nitrating sheds, which he had been unable to explain because he was not aware of the danger of nitrogen-oxid fumes in that factory.

Some light is thrown on these cases by the report of an autopsy performed by G. A. Apfelbach, of the Illinois State Factory Inspection Department, for W. E. Evans, Coroner of Lake County, Ind., on the body of an exceptionally big and muscular man who had been a hard drinker, and who just before applying for work at the gun-cotton plant had been on a heavy drinking bout. He had gone on with the night shift, and during that time the nitrous fumes were not bad enough to make any of the other men apply for treatment at the company dispensary. He had worked only four hours in the nitrating room when he began to suffer from the fumes and went out, saying, "This smoke is too much for me." Almost at once he lost consciousness and died in about thirty minutes. Apfelbach found the larynx, trachea, and bronchi, hyperemic; the lungs congested; the alveoli containing frothy fluid. The heart was absolutely negative, as were also stomach, intestines, kidneys, and brain; but the spleen and liver were congested, and the blood was dark and fluid. A tubeful of blood was taken to McNally, chemist to the

coroner's office of Cook County, and he found a small quantity of nitric oxid, but no methemoglobin. Death must have been caused by the action of the poison on the lower centers, especially the respiratory center.

Before the war nitric acid was little manufactured in this country, but with the war came the necessity for meeting not only the usual demand, which had formerly been largely supplied from Germany, but also the demand of the explosives industry. All explosives in use in the war were nitrated products, except ordinary gun powder, the manufacture of which is fortunately not attended with any exposure to poisoning. For the making of trinitrotoluene, of smokeless powder (which is nitrocotton), of mixed powders (which are made from nitrocotton and nitroglycerin), of picric acid (which is trinitrophenol, made by nitrating carboic acid), and of the less well-known tetryl and TNA,* as well as the detonator, fulminate of mercury, great quantities of nitric acid were needed. The plants that went up at first were, for the most part, largely experimental, the engineering and chemical problems had not been solved, and as a result many accidents occurred; for in these processes strong nitric acid is poured over cotton, or carboic acid, or mixed with glycerin or toluene, and the effect is to raise the temperature and to form oxid gases.

Nitration of cotton to make nitrocellulose, and of phenol to make picric acid, are attended with the greatest danger from fumes of the oxids; nitration of glycerin to make nitroglycerin, with the least danger. Between these two extremes come the manufacture of nitric acid and the nitration of toluene, benzene, naphthalene, anilin, chlorbenzene, and dimethylanilin.

The nitric acid industry is now established in this country and, although not as extensive as during the war, it is still considerable. One of the chief uses of nitric acid is for the manufacture of nitrocellulose which is made, like guncotton, by nitrating cotton or shredded tissue paper. Nitrocellulose is the basis not only of celluloid but of many coating materials for leather, pencils, etc. It is the basis of airplane dope. It is the material from which moving picture films are made. It is the artificial isinglass used in the curtains of automobiles. The acid used for this kind of nitrocotton is not so strong as that used for military guncotton, and the fumes are less heavy, and, therefore, there is less danger of fume poisoning. This acid is also used to prepare metals for plating and, as the metal drops into the acid bath, a cloud of orange fumes always rises, and should be carried off by proper suction.

Nitric acid is used in etching. According to a report issued by the International Labor Bureau (14) photo-engravers are exposed to nitrous fumes and the danger is always present if the acid used is

* Tetryl is tetranitromethylanilin and TNA is tetranitranilin.

over 15 per cent in strength. This is said to be a serious feature of the work in Italian photo-engraving; and the mortality among these men is high. Nitration is an important step in the manufacture of coal-tar dyes and drugs and it is, of course, a step in the production of nitroglycerin, the most important peace-time explosive.

An important source of nitrous fume poisoning which persists in peace-time is the incomplete detonation of a blasting charge in mining. This has been the cause of much trouble in the mines of the Rand, where every year many accidents take place, causing loss of time, disablement, and death. The air of mines does not often contain dangerous amounts, but when the explosive used for blasting is only partially detonated and burns instead of exploding, very large amounts of gas may be produced. Therefore such accidents take place after blasting, and usually within the first hour. A typical instance of this kind is given by Irvine (15) of Edinburgh, who made a study of gassing in the South African mines. "Two white men and three natives were working at the end of a drive, with a cross-cut leading off from it about 100 feet from the face. The miners in the cross-cut blasted at 3 p.m., before the party in the drive had left, and without giving them warning. The latter were imprisoned in the drive for three-quarters of an hour. They felt that they were being gassed and turned on the compressed air; then went to the surface as soon as the smoke cleared. The white men washed, changed, had their evening meal and went to their quarters, as usual. Acute respiratory symptoms came on in both at 10:30 p.m. and when seen by Dr. Macaulay at 11:00 p.m., they were too ill to be removed to the mine hospital, a few hundred yards away. Both eventually recovered under energetic treatment. None of the Negroes reported sick at the time but the next morning one was found dead, another moribund, and the third so ill that he, too, succumbed."

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HYDROFLUORIC ACID, HF

This acid is used to etch glass or to polish cut glass. It is intensely caustic to the skin and conjunctiva and is the source of many troublesome but usually slight accidents in factories which employ it even in very small quantities. Ronzani (1) tested the vapors on animals and found that protracted inhalation of: 0.66 parts per 1000 kills animals in $1\frac{1}{2}$ to $1\frac{1}{2}$ hours; 0.25 to 0.05 per 1000 kills animals in 1 hour to 3 days; 0.01 per 1000 produces ulceration of the mucous membranes and broncho-pneumonia and, if the animals survive, disturbance of nutrition. There is a severe anemia and a loss of defensive substances against infectious organisms. Thus, in guinea pigs, rabbits and pigeons he found that exposure to fumes of hydrogen fluorid was followed by loss of red corpuscles; that the serum agglutinated typhoid bacilli in dilutions of only 1 to 950, while the serum of controls agglutinated in dilutions as high as 1 to 1900; and that while control animals could destroy in 48 hours all the bacilli prodigiosi injected into the lungs, the animals exposed to HFl still harbored living bacilli after 60 hours, 72 hours and 90 hours. The strength of gas used in these latter experiments was 0.01 per 1000 parts of air. Experiments with as little as 0.003 to 1000 proved negative.

According to Rambousek (2), the production of artificial fertilizer by adding sulphuric acid to raw material containing insoluble basic phosphates (to change them to soluble acid phosphates) may cause the evolution of very irritating and dangerous fumes of hydrofluoric and silicofluoric acids.

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CHAPTER 25

HYDROCYANIC ACID AND CYANIDS. CYANOGEN CHLORID. CALCIUM CYANIMID

HYDROCYANIC ACID OR HYDROGEN CYANID (HCN) AND ITS COMPOUNDS

HYDROCYANIC acid is a colorless transparent liquid, extraordinarily volatile (more so than ether), and giving off vapors lighter than air which have the characteristic odor of bitter almonds. The vapors of HCN may be emitted from the cyanids of potassium and sodium when moist, and the action of these salts is practically the same as that of the acid, but neither is so toxic, nor is cyanogen, CN, so toxic as HCN. The double cyanids, ferro- and ferri-, are non-toxic. According to Geppert (1), hydrogen cyanid is a true protoplasmic poison to both plants and animals. The effect upon protoplasm is due largely to the fact that it retards oxidation, that oxyhemoglobin is not reduced by the respiration of the cells, that the tissues no longer absorb oxygen, with the result that the venous blood is bright red, that there is an increase of sugar and lactic acid, and that the nitrogenous bodies in the urine are increased. Cyan-hemoglobin, however, cannot be demonstrated in the living body. Hydrocyanic acid is rapidly changed in the body and is excreted in part as sulphocyanids in the urine (2).

Von Jaksch (3) classes hydrogen cyanid with those poisons (oxalic acid, for instance) which cause "internal suffocation in the presence of abundant oxygen." In very acute poisoning the symptoms come on almost at once, the victim suddenly collapses with a cry of terror, he breathes deeply and hurriedly, then passes into convulsions, with irregular respiration and bloody froth on the lips, and within a few minutes he is dead. If the dose is smaller, the onset of symptoms may be delayed for fifteen minutes or more, beginning with distress in the heart region, headache, dizziness, nausea, and a feeling of oppression, after which the victim begins to stagger and perhaps vomits. The respirations are quick at first, then slow and irregular, the heart sounds are weak and the pulse hardly discernible. The breath smells like bitter almonds. There may be transient hallucinations and disorientation; later symptoms of nervous irritation come on. The pupils are wide and fail to react, the muscles of the jaw are fixed. There is opisthotonos or

general convulsions, and the skin is cyanotic, covered with cold sweat. In fatal cases profound coma precedes death. Tintemann (4) finds evidence of degeneration of the kidneys, for the urine may contain a great quantity of albumin or degenerated cells and casts.

The autopsy findings in two fatal cases were recently published by Thomas (5) and they may be briefly summarized as follows: There was an absence of odor of cyanid before the body was opened but after opening, the odor was detected in all the serous cavities and still more strongly in the lateral ventricles; the face was livid and so was the mucosa of the mouth and the nails were blue; the intestinal and gastric mucosa, pink; the intima of the aorta a bright pink; the liver a uniform blue green; the gray matter of the brain green; there were extravasations of blood into the tissues of the stomach wall posteriorly; the myocardium was flabby; there were no putrefactive changes, no odor of putrefaction, none of the usual postmortem staining. The chemical and spectroscopic tests were positive. Lambert (6) made an autopsy on a man employed in disinfecting, who lived for 16 days after inhaling HCN gas, and he found nephritis, adherent meninges and multiple small hemorrhages in the cerebral tissue. Microscopically the Betz cells showed cloudy swelling, the Purkinje cells had largely disappeared, and there was gliosis in the pontal lobes.

A mild form of acute poisoning from hydrogen cyanid is described by Fühner (7) who says that men engaged in spraying trees with HCN suffer from sudden faintness, an imperative desire to go to stool, trembling of the muscles, weakness, palpitation of the heart, and then a splitting headache. The warning signs are itching of the throat and nose, burning and reddening of the eyes, then a metallic taste in the mouth and burning of the tongue, and finally pressure in the head and a feeling of apprehensiveness. Tatham (8) saw a case of temporary blindness which came on after exposure to dilute hydrocyanic acid (cleaning old gold lace with a rag dipped in the acid) and passed off after five to six hours. The eyes were perfectly normal in appearance and there was no intolerance to light, only a sudden, transient, one-sided blindness.

There are few fatalities reported in ordinary industry. One is reported from Germany, in a woman who carried a jar of potassium cyanid down a flight of stairs to the galvanoplasting room and on the way inhaled enough fumes to cause her death. Most of the cases of fatal poisoning have occurred since the outbreak of the war because of the extensive use of hydrocyanic acid for the destruction of vermin, for which purpose it continues to be used. Lambert's (6) case was in an Italian disinfector who was found unconscious in a room filled with this gas. The immediate symptoms were: stertorous breathing, flushed skin, veins red and engorged,

pupils contracted and muscles rigid. Later there was free sweating and muscular twitching. The man lived 16 days, with fever, sweating, tremors and rigidity of the muscles, occasional convulsions, ataxia and aphasia.

As to the quantity of HCN which is dangerous to life, opinions have changed since the experience gained during the war. Lehmann says it is not true, as was formerly supposed, that this gas is more dangerous to man than to lower forms of life, rather the contrary. Kobert, writing in 1902, had said that 0.3 part per 1,000 of air would quickly kill both men and animals, but Katz and Longfellow (9) quote Kohn-Alrest as saying that 1.0 part per 1,000 cannot be breathed for many minutes. In experiments with rats made by the United States Public Health Service 1.0 part per 1,000 killed in ten minutes, 0.5 part failed to kill in that time, and 0.1 seemed to be safe for rats. Men at rest stood 0.25 part per 1,000 for two minutes, and 0.375 for a minute and a half without dizziness. Even 0.5 was endured for one minute without injury. They believe a degree of tolerance to the gas is acquired. For fumigation, they advised sending an experienced man into an atmosphere shown by test not to contain more than 0.1 per million parts of air, but carrying a gas mask with him. If no mask is available the gas in the air should be below that limit of concentration. The test recommended is described in an article by Katz and Longfellow.

Schnellen (10) tested the effect of measured doses of hydrocyanic acid vapors on cats. He found that exposure to 0.3 and 0.4 part per 1000 of air for three or four hours had no effect, but as soon as the amount of the vapor was raised to 0.5 grave symptoms appeared after an hour and a half, such as deep respiration, increased salivation, dilatation of the pupils, cramp and vomiting. If the animal is kept in this atmosphere for a period of from two and a half to five hours, he dies, and if the proportion of the vapor is raised to 1.2 or 1.5 per 1000 death occurs within thirty minutes, accompanied by the foregoing symptoms. In calculating the amount of hydrocyanic acid necessary to destroy life, the dose is found to vary from 1 to 5 mg. for each kilogram of body weight of the animal. For man it is calculated that 60 mg. would be the minimal lethal dose, or from 0.8 to 1.0 mg. for each kilogram of body weight.

A large number of fatalities from the use of hydrocyanic acid in fumigation have been reported since the war in the daily press, but the records of the Public Health Service cover only those which have occurred in the fumigation of vessels under the supervision of that service, together with one in a building in New Orleans during a plague eradication campaign. Their records, for which I am indebted to Acting Surgeon General White, show that in February, 1916, there were three deaths, then none till 1920, and between June, 1920, and July, 1923, there were 18, but four of these

were in stowaways. The man who died in New Orleans had not followed instructions to open the building from the outside, and then wait till it was fully aired before entering. Instead, he tried to pass through it from the roof to the lower floor, but was overcome by the gas and died before he could be rescued.

The indiscriminate use of this very dangerous gas by persons quite unfamiliar with it led to the accidental death in Cleveland of four persons who inhaled hydrocyanic acid gas with which a restaurant under their apartment was being fumigated. As a result, the city of Cleveland has passed an ordinance forbidding an unlicensed person from using deadly gases for fumigation purposes and providing a substantial bond for fumigation operators.

Koelsch (11), in 1920, discussed this new problem in public health. He says that hydrocyanic acid has been used in the United States for fumigation since 1886, but only recently in Germany. Its introduction has brought a new responsibility to the industrial hygienist because it endangers not only the persons who go back to the disinfected rooms but the men who carry out the disinfection. The usual method in Germany is to bring about the evolution of hydrocyanic acid fumes by means of dilute sulphuric acid and sodium cyanid. The gas begins to come off immediately, so that great precautions must be taken. The disinfectors are instructed to drop the package of sodium cyanid, paper and all, into the acid, and run. In a building of several stories the disinfection must begin at the top story and in the room farthest from the stairway. After the doors are closed they must be sealed and warning signs placed on the outside. The action of the gas is complete in two hours, but usually the building is left overnight. The doors and windows must be opened from the outside, and when this is impossible an oxygen helmet must be used. From half an hour to two hours' ventilation is long enough for the disappearance of the gas, but the apparatus in which it has been generated must be removed with great care, as was shown by the first fatal case of poisoning from this source in Germany, reported in 1917. Two men went in to carry out the receptacle in which the gas had been produced. As they lifted it, an unchanged portion of sodium cyanid was brought in contact with the acid and the fumes that developed poisoned the workman who was carrying the rear handles of the apparatus. He died in a short time.

Fülmer (7) tells of 100 soldiers who put on deloused clothing too soon, before they had had sufficient airing, and all were poisoned, ten losing consciousness, but none of them suffering any permanent effect. He tells also of an accident in Essen in some Krupp workmen's barracks which had been treated with the gas and then imperfectly aired. Ten men died from the fumes, and five were comatose, but revived. It is possible that HCN plays a more im-

portant part in connection with certain forms of industrial gas poisoning than has been realized as yet; for it is produced in varying quantities in such processes as the distillation of nitrogenous organic compounds or the incomplete combustion of such compounds, and therefore it may be present in illuminating gas, in blast furnace gas, in the fumes from burning celluloid, in the distillation of coal-tar, in making Prussian blue, and, according to Koelsch, in the use of the lime residue from gas works to remove the hair from skins in tanneries.

Kockel (12) says that eight deaths in a burning celluloid factory in Leipzig in 1900 were due to fumes of hydrogen cyanid. These persons must have been overcome very quickly, for six of them were found dead in a room near the entrance, and they had died without making any outcry. In four bodies the odor of prussic acid was detected and in all the blood was bright red and very fluid. Kockel burned celluloid, which is simply dinitrocellulose, with 40 to 50 per cent camphor and analyzed the resulting fumes. He obtained from five grams, about as much as is in a small comb, an average of 0.05 gram of HCN and since Kobert says that a fatal dose is 0.05 to 0.06 gm. Kockel estimates that the fumes from burning a comb would be enough to poison a human being. As we have seen, Kobert's estimate is now considered too small. Kockel's rabbits, killed by the fumes, had both CO and HCN in their blood, but he considers the former less significant.

Another source for hydrogen cyanid gas is, according to Katz and Longfellow, of the Bureau of Mines, the MacArthur-Forrest cyanid process for the extraction of gold and silver from ores by the use of cyanids of potassium and sodium, and Leybold (13) says that there was a case of fatal poisoning in a man preparing ammonium sulphate, from the HCN and H_2O which were evolved.

Chronic cyanid poisoning from HCN and its compounds is certainly rare and there are even skeptics who refuse to believe that any indubitable cases have ever occurred. Fühner, on the ground of animal experiments, believes that the condition brought about by repeated exposures is not chronic poisoning but rather increased susceptibility.

Koelsch says that chronic poisoning has not been observed at all in a great gold and silver refinery in Frankfort on the Main where a weak solution of hydrocyanic acid has long been used. Very small quantities of this acid seem harmless, probably because it takes up sulphur in the body and is changed to the non-toxic sulphocyanogen. He himself has been unable to discover any disturbance of health in the factories he has visited. Chanet (14) described cases among workers in a galvano-plating factory where, however, there was a distinct odor of oil of bitter almonds.

One of the cases of chronic poisoning in the earlier literature

which is often quoted is Martin's (15). This was in a 21-year-old servant girl, perfectly healthy when she entered on her employment with a woman who applied a silver coating to antique objects by means of a mixture of chalk and the double cyanid of potassium and silver. The girl had the polishing to do and inhaled cyanid-laden dust and cyanid fumes. Her first symptom was languor, later nausea, cough and dyspnea, headache and backache and so much exhaustion that she was obliged to go to bed. The doctor found her breath smelling of bitter almonds, her face was pale at first, then red, her pulse was small, soft and quick, she had a quick, irregular respiration which was painful, and she complained of pains in her back and in her chest. Later obstinate vomiting came on, with cramps of the diaphragm and of the abdominal muscles girdle pains and great weakness, so that she could not sit up. This lasted for 15 or 16 days and then there was a very slow improvement. At the end of a month she could walk but she had profound anemia, weakness, sleeplessness, headache, ataxic gait with inability to stand upright with her eyes shut. These symptoms lasted for seven months, after which there was a slight improvement under electrical treatment but there was a reaction of degeneration in the legs.

Kobert (16) reports two cases of chronic poisoning from the use of cyanids in gilding. One of the men had at first nausea, difficult breathing, a sense of weariness, which passed off, but he fell into a condition of cachexia, while the other died after a period in which he suffered from digestive disturbances, unsure gait, difficulty in moving his jaw.

Merzbach (17) gives a very full description of a case of chronic HCN poisoning ending in death. The man, who was 44 years old, had worked for thirteen years in an art printing establishment. His duty was to place copper plates in a solution of the double cyanid of silver and potassium and then the galvanic current split off the silver which was deposited on the copper and the released CN was in part joined to the hydrogen released by the same current from water. As the covers for these galvanizing tubs were imperfect, the fumes of HCN escaped. Another task was the cleaning and brushing of the plates when they came out of the tubs, which scattered cyanid dust into the air. The man had noticed a taste of bitter almonds from time to time. His illness began at about the end of the first year and increased in severity till his death about six months after he was forced to quit work. It was characterized by severe gastro-intestinal disturbance, vomiting, abdominal cramps, obstinate constipation, and by general functional disturbance of the whole nervous system with involvement of the intellect.

An unusual form of cyanid poisoning resulting in the clinical picture of acute anterior poliomyelitis was reported by Collins and

Martland (18) in 1908. The man was an Italian, 68 years old, and for two years he had been polishing silver in a hotel, dropping the silver into potassium cyanid solution and drying it. His hands and forearms became brownish red and itched badly, and the fingernails were quite black. If he held his hands near his face, so that he breathed the fumes from them, he would become quite dizzy. His illness came on suddenly with symptoms of meningitis lasting four to five days, but then passed leaving a loss of power in the legs and arms, and after 48 hours he could not stand. There were no sensory symptoms. The loss of power in the muscles of legs and arms persisted for six months and then slowly improved. This rapid and intense intoxication involving the spinal cord differed from lead and arsenical poisoning, especially in that there were no premonitory symptoms. The authors were able to produce in animals peripheral neuritis with axone degeneration and secondary degeneration of the anterior horn cells.

Recently, studies have been made by C. I. Reed (19) of the University of Kansas on chronic hydrocyanic acid poisoning in animals, and these have been followed by a report of fourteen cases of chronic industrial poisoning from cyanogen chlorid. The men were employed in a small plant manufacturing this compound, but when seen by Reed they were no longer doing that sort of work so that he could not record objective symptoms. However, careful questioning of the men brought out a fairly definite clinical picture of the condition brought on by breathing small amounts of the gas. A typical history is given as follows: The man was exposed to cyanogen chlorid every day for eight months, during which time he suffered three severe exposures causing dizziness, nausea, profuse lachrymation, blurring of vision, gasping, coughing, staggering, and prostration that lasted several hours. Chronic symptoms were muscular weakness, lassitude, congestion of the lungs, irritation of the skin, hoarseness, conjunctivitis, edema of the eyelids, and burning urine. There were also periods in which the pulse was irregular but which bore no relation to heavy exposures. His appetite was decreased after severe exposures, but at other times was abnormally increased. During this period his weight fell from 170 to 150 pounds, but at the end of five weeks, after change of occupation, he regained ten pounds.

The other men suffered from much the same symptoms, though sometimes the loss of weight was greater, sometimes mental disturbances were complained of, and sometimes there was blistering of the skin. While these symptoms resemble closely those reported for other cases of chronic cyanid poisoning, the possibility of an additional factor, the chlorin radical, was indicated by the loss of weight, congestion of the lungs, and cutaneous manifestations. Reed experimented with cyanogen chlorid administered to dogs under the

skin and in vapor form, and also with vapor of hydrocyanic acid. The animals died with much the same train of symptoms when given lethal doses, but when smaller doses were administered there were certain points of difference between the action of hydrocyanic acid and of cyanogen chlorid: the loss of weight is greater from the latter, the increase in heart rate is greater, there is congestion of the lungs, depression is more pronounced, and there are greater muscular disturbances. It seems probable that this difference in action of the two compounds may be dependent upon the presence of chlorin in the cyanogen chlorid. The symptoms of chronic cyanogen chlorid poisoning are more severe than those resulting from the more common cyanids.

Winternitz, Wislocki and Finney (20) say that the acute changes caused by cyanogen chlorid are confined to pulmonary edema and congestion, with a very mild inflammatory process in the bronchioles. In less severe cases, there is a catarrhal bronchiolitis, with a slight, localized emphysema and rarely with small patches of broncho-pneumonia.

CALCIUM CYANIMID

Calcium cyanimid, CaCN_2 , has come into prominence recently in connection with the use of atmospheric nitrogen for the production of ammonia, nitric acid, calcium nitrate and nitrite, and calcium cyanimid. The utilization of the nitrogen of the air has been carried on for some time in Norway where there is abundance of the water power necessary for this electro-chemical industry. Lately it has been carried on in electric furnaces at Niagara Falls. Calcium cyanimid is used in the United States to produce ammonia, usually as a stage in the production of nitric acid. In Italy there is now a large production of calcium nitrate and cyanimid for use as fertilizer, especially for rice fields. It is apparently causing a good deal of trouble when used in this way. Pavia (21) reports in 1920 the distressing lesions set up by calcium cyanimid when the peasant scatters it by hand and it falls on his sweating skin. Very severe lesions are produced on the mucous membranes of the nose and throat, and on the skin, especially of the forearms, lesions occur which take from 25 to 40 days to heal.

During the war CaCN_2 was used in one large TNT plant for the production of nitric acid. It was found that the dusty impalpable black powder was very irritating, so much so that the men who unpacked it could be allowed to work only four hours, after which they must bathe. The powder seemed to eat into the skin and severe cellulitis, and even abscesses followed. A curious systemic effect was observed in this plant, but only when a man took a drink of alcohol. Then, even if he drank very little, pronounced vaso-

motor depression occurred,—flushing, sweating, rapid pulse, headache, ringing in the ears, and dyspnea. These symptoms disappeared after from 24 to 48 hours. In one case the attack was brought on by a dose of paregoric for diarrhea. This observation made to me in a personal communication by Dr. H. G. Lampson of Barksdale, Wisconsin, is confirmed by Langlois' (22) article published in Paris in 1918. After speaking of the dermatitis in workers with CaCN_2 he calls attention to the serious effect of alcoholic drink on these men. There occurs a sensitization of the vasodilator centers so that a small glass of wine is liable to send the pulse up to 104 with a fall of blood pressure, rapid respiration, and sometimes fainting. One man had syncope after drinking only thirty cubic centimeters of red wine, and the syncope returned whenever he raised his head; he had nausea, a very low blood pressure, and extreme dilatation of the vessels of the face and conjunctiva. Langlois' experiments on animals confirm his clinical observations.

The experience in Germany is very similar. Hesse (23), writing in 1921, says, "In connection with cyanimid, which has attained such great importance as an artificial fertilizer, it has been found that persons working with it are attacked by fleeting exanthemata of the head and chest. There is rapid breathing, increased heart action, and low blood pressure. The attack lasts an hour or two. The curious feature of the attack is that it only comes on when the patient has consumed alcohol in some form." Hesse's explanation is that cyanimid is able to energize the action of a number of substances, such as chloral hydrate, sodium bromid, thiobromin, etc. For example, a man experimenting on himself took a dose of cyanimid in the morning, and in the evening when the experiment had been quite forgotten he took a glass of beer. The typical symptoms came on and the attack lasted six hours. Hesse gave a guinea-pig a physiologically inactive dose of sodium bromid followed by a small dose of cyanimid, and there was an immediate effect as if the animal had been poisoned with a large dose of the bromid.

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CHAPTER 26

HYDROGEN SULPHID. CARBON DISULPHID

HYDROGEN sulphid, sulphuretted hydrogen, H_2S , is one of the asphyxiating gases, very rapid in its action if sufficiently concentrated, but, like hydrocyanic acid and carbon monoxid, usually leaving no permanent effect on men who survive. According to the late W. H. Hudson of the Du Pont de Nemours Company, the feature which has made H_2S dreaded in sulphur dye works is the startling suddenness of its attack, not the lasting effect for it is the general opinion among industrial workers that men who are "knocked out" by it either die or recover completely.

Kobert (1) gives a comparison between the action of three asphyxiating gases, HCN , CO and H_2S . The lethal dose for the first is 0.12 per 1,000 parts of air, of H_2S , it is 0.5. Taking Haldane's figures of 1.5 per 1,000 as the lethal dose of CO , hydrogen sulphid is seen to occupy a place between the two others. The action of the three is very similar. Death may come on like a stroke of lightning, as in HCN poisoning, but usually there are first symptoms of irritation of the nervous system, which occur even earlier than the formation of H_2S —hemoglobin. This last is of more theoretical than practical interest, for it cannot be produced experimentally in warm-blooded animals who die from the effects of H_2S before much of the hemoglobin has been altered. (See Kobert.) Haggard (2) finds that H_2S is transported in the blood in a loosely combined form, easily dissociable, for when injected into any of the body cavities it can be almost at once detected in the expired air. The active physiological action is exerted by the gas in solution in the blood and when inhaled it does not form a combination with hemoglobin.

The inhaling of as much as 0.5 part of hydrogen sulphid per 1,000 of air is fatal (1) but not till after the lapse of many hours and then by edema of the lungs (3). Concentrations of 0.8 to 2.0 parts per 1000 produce exaggerated respiratory efforts (hyperpnea) followed in a few minutes by death—in apnea vera. A quantity higher than this, 3.0 per 1000, causes almost instantaneous death, by paralysis of the respiration. Apparently the stimulating action on respiration is exerted on the afferent endings of the vagi in the lungs, the hyperpnea causes an excessive loss of CO_2 and the blood alkali is reduced, just as it is in the hyperpnea of ether and of

nervous excitement, and in carbon monoxid poisoning and in an atmosphere of low oxygen. Small quantities of H_2S do not affect the respiratory center, large quantities paralyze it (4).

In case death is not instantaneous the symptoms are those of irritation of mucous membranes, reddened and smarting eyes, catarrh of nose and throat, cough, and of nervous irritation, difficult breathing, palpitation of the heart, dizziness, headache and cold sweat. If the immediate effect is not fatal, bronchopneumonia may develop. Autopsy on men dying suddenly from the inhalation of a large quantity of H_2S reveals no change, not even in the blood, but in slower cases there is edema of the lungs or pneumonic areas, and an odor of rotten eggs. The body may have a greenish brown tint (1).

Haggard, Henderson and Charlton (4) draw attention to the curious fact that the body can handle H_2S up to a certain limit without any ill effect, but a slightly larger quantity is quickly fatal. It is an acute poison, comparable to the cyanids, yet it is frequently formed in appreciable quantities in the intestines and may be excreted in the breath of persons who are virtually healthy. Nevertheless there is evidence in industry, as we shall see presently, that exposure to small quantities of hydrogen sulphid over a long period may cause symptoms of chronic poisoning.

It is said to give off the characteristic odor of rotten eggs when present in a concentration of only one-tenth part in 1000 parts of air, but industrial accidents occur not infrequently without any warning odor being noticed.

Industrial poisoning from sulphuretted hydrogen is almost always the result of an unforeseen accident, perhaps most often the unsuspected formation of the gas by the decomposition of organic matter. Thus Tauss (5) tells of accidents in German tanneries when the sludge left in the tanning vats decomposes and the gas is produced. He gives the history of four cases in 1916, all fatal, and of four in 1920 only one of which ended in death. In both instances the men were overcome by the gas with great suddenness, lost consciousness, and their would-be rescuers suffered the same fate. Tauss also tells of H_2S poisoning in a fat-rendering plant where bones were treated with steam and the fat melted out was mixed with lime and collected in iron kettles. A young workman was sent in through the manhole of one of these kettles to clean it out and fell dead, as did a second man who went to his rescue, and the foreman who was lowered in with a lifeline about his body was drawn out unconscious, but he recovered.

In a large American glue and lubricant factory in 1918 three men were overcome with this gas and two died within a few minutes. These two had been sent in to clean out a tank which had been filled with glue made from hoofs. They were asphyxiated almost at once and a third man put on a helmet and went in to drag them out. On

the second trip he began to feel faint and dizzy but revived in the open air. The latest reports of the German factory inspection service tell of several instances of poisoning by hydrogen sulphid. In Leipzig four men were killed by this gas while cleaning out the drain pipes of a fur-dressing plant, three of them dying in an attempt to rescue the first, who had fallen in a faint. The gas had been formed by the decomposition and putrefaction of the animal matter in the drain water, helped by the presence of iron sulphid and sulphuric acid in the water. It was noted in this case that the gas did not betray itself by any odor. Legge (6) tells of the heroic rescue of two men who were overcome by sewer gas in a sump hole at the Luton Sewage Farm. The first man who entered was killed by the gas, the second who went to help him was rescued in time by the third who in his turn was overcome but revived.*

Hydrogen sulphid may be liberated in the course of chemical reactions for the production of coal tar dyes or industrial chemicals. Many instances of this kind came to my attention during the war when the great demand for coal tar colors led to the opening of poorly constructed and ignorantly operated plants. This danger is connected with the manufacture of sulphur colors, especially sulphur browns and khaki, much less with the manufacture of sulphur black and still less in connection with sulphur blue. Hydrogen sulphid is formed and great precautions are now taken to prevent its escape, but these precautions are the result of sorry experience during the early days of war-time dye production. I was told of a man who went into an empty pressure tank in a sulphur brown department too soon after it was emptied and was completely knocked out in five minutes. A second man who simply bent over the manhole was also overcome, but neither died and neither seemed any the worse the next day. Several cases were related of pipe fitters or carpenters who while working on platforms or ladders in such plants were overcome by the gas and fell, sustaining serious injuries.

A fatal case occurred in a chemical works manufacturing sulphur monochlorid and another in a works which produces the new parasiticide, barium trisulphid. A tank containing this compound stood out of doors in the sun and a workman was told to uncover it. He drew off a plank and then went round to the other side to pull off a second one, but fell to the ground unconscious and a second man who ran to him to see what was wrong also dropped to the ground. The first man died, the second was resuscitated. It was found that the escaping gas was hydrogen sulphid.

Rambousek (7) tells of some Austrian cases in 1907, similar to these. Barium sulphid was being used to form barium carbonate

* Taylor, *Medical Jurisprudence*, 12 Amer. ed. 1897, p. 486, says that Paris sewer gas contains on analysis in 100 parts, nitrogen, 81.2; CO₂, 2.0; and H₂S, 2.99.

by passing CO_2 through it, in the course of which H_2S was formed but was burned, oxidized, for the manufacture of sulphuric acid. One night by accident there was an escape of H_2S and the gas penetrated into a room near by, where three plumbers who were employed on the night shift had gone to sleep. Two hours later they were discovered in a dying state. A second accident, told by Rambousek, came from the decomposition of barium sulphid. Here, too, the sulphuretted hydrogen escaped because of the breakdown of the steam jet which was supposed to carry off the fumes and a workman who was affected was in a comatose state for two days. In Baden, according to a recent report of the German factory inspection service, three workmen were overcome by this gas and one died, but the two others recovered rapidly as soon as they were removed from the poisoned atmosphere. This accident took place in a tannery, but was not of the usual kind. The men were filling a vat with "kalzin," said to be a sulphur derivative of calcium. By mistake they added lactic acid instead of more kalzin and the contact of the acid liberated hydrogen sulphid.

W. Gilman Thompson (8) says that fatal poisoning has occurred in bottling mineral waters, and the United States Bureau of Mines gives H_2S as one of the dangerous gases encountered in mining, either as a result of an explosion or in occluded coal seams, produced by the decomposition of pyrites in moist air. Sometimes it is held in pools of water and liberated when the miner walks through the water and stirs it up.

From European sources we learn of poisoning from H_2S in the vapors from soap works when decomposed fat is rendered, and in making illuminating gas and coking when the waste gases are removed by washing with sulphuric acid and passing over an oxid bed. These gases may contain as much as 16 per cent of H_2S and fatal poisoning may occur in cleaning out such an oxid bed. (Glaister and Logan.)

Canby Robinson (9) reported in 1916 a case of hydrogen sulphid poisoning with unusually full details. Much of the history reads like CO poisoning. The victim, a healthy workman 44 years old, was put to work at a tank of copper sulphate solution through which hydrogen sulphid gas was passing. He was out of doors and he did not notice much odor but suddenly he became dizzy and began to see blue and green colors. He tried to move away or call for help but fell unconscious to the ground, and although he soon recovered consciousness he found he could not raise his head. When he reached the hospital he was dazed, his pulse irregular in force and rhythm, 66 per minute; there was no dyspnea, nor cyanosis, but the pharynx was somewhat reddened and throughout both lungs suberepitant râles were heard. There was a leucocytosis of 20,900, 88 per cent of which were polynuclears.

The feature that made this case specially interesting was a typical auricular fibrillation which lasted several hours. The man made an uneventful recovery, left the hospital and went back to work for the same company, apparently in perfectly normal condition.

As for the chronic effects from continual exposure to smaller quantities of hydrogen sulphid, the literature does not yield much positive data. Doremus and McNally (10) say that workmen in daily contact with the gas develop conjunctivitis, headache, and permanent gastric disturbances. The countenance becomes pale. The skin has a tendency to become furunculous. Chemists who frequently work with hydrogen sulphid are troubled with nervous headache in later years, and become exceedingly sensitive to this gas which was at former times not unpleasant to them. Severe colic, "plomb des fosses," is brought on shortly after the inhalation of even very dilute gas—sometimes only a few whiffs. The depression of the nervous system is also distressing.

At the Brussels Congress of Industrial Hygiene in 1910, René Sand reported a case of "combined sclerosis of the spinal cord and polyneuritis, consecutive to prolonged inhalation of hydrogen sulphid." A workman, 38 years old, robust and with no hereditary taint nor alcoholism nor syphilis, worked for two years in a sulphur black establishment where so much H_2S escaped that people living near complained that their silver turned black. In April, 1905, he had ataxia, pains, paresthesias, muscular atrophy, reaction of degeneration, first of the lower limbs, then of the upper, narrowing of the visual field. The spinal fluid was normal. By December, 1906, he was completely blind, cachectic, with pain and paresthesias persisting, and he died of bronchopneumonia in May, 1910.

The microscopic examination of the spinal cord showed no inflammation but an extensive degeneration of the pyramidal tracts, and posterior columns in the dorsal cord, of the direct cerebellar and Gowers in the lumbar cord and of the pyramidal only in the sacral. The degeneration was less accentuated in the roots and still less in the nerve trunks, except the optic nerve which was completely atrophied. Most of the anterior horn cells in the whole length of the cord showed atrophy or chromatolysis and some had disappeared. There were no signs of syphilitic changes in the vessels. In favor of the theory that this was a case of chronic H_2S poisoning, Sand mentions the lymphocytosis and eosinophilia observed at the outset.

Sayers (11) of the U. S. Bureau of Mines recognizes two types of industrial poisoning by hydrogen sulphid, the acute and the subacute. In acute poisoning the symptoms are those of asphyxiation, in subacute, of irritation, and the pathology of the two follows these differences. In subacute cases pain in the eyes, followed by conjunc-

tivitis is fairly constant while bronchitis and pains in the chest are frequent. There is destruction of the lining of the lungs, together with inflammation and edema, while in acute cases there is no characteristic lesion. The exact limit of danger is not yet established but it is evidently below 0.05 per 1000 of air.

Hoppe (12) describes the effect on the eyes as follows: In a sulphur factory in which hydrogen sulphid is formed as an intermediate product the employees are attacked from time to time by an extremely painful inflammation of the eyes with swelling of the lids, photophobia, and hyperemia of the conjunctiva. It is characteristic that these symptoms usually come on some hours after the workmen have left the hydrogen sulphid fumes and also that there is no other disturbance of health. The warning signs consist in the appearance of a colored ring around the light and an increased sensitiveness to all kinds of light. The extreme photophobia is probably caused by an affection of the corneal epithelium. Since hydrogen sulphid does not possess any real caustic action, Hoppe is inclined to believe that the irritation is an indirect effect following a previous inhalation of some poison so far not isolated, but though this point is still obscure there is no doubt that workmen should be protected against these fumes by gas masks.

The irritating action of hydrogen sulphid fumes on the eyes is noted by workmen in a large American artificial silk factory where in the course of the process cellulose xanthate is spun under dilute sulphuric acid and sodium sulphate to make cellulose hydrate. Small quantities of H_2S are given off, enough to make the men's eyes smart and feel "as if they were full of sand."

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CARBON DISULPHID, CS_2

Carbon disulphid is an industrial poison to the literature of which Americans have made noteworthy contributions, though not so extensive as those of Continental writers, it is true; but this is not due to neglect of the subject in the United States but to the fact that carbon disulphid is not used extensively in American industry, as it is in France and Germany. Medical literature in those countries is full of descriptions of deplorable conditions in rubber factories where large quantities of this compound are used, and although English rubber manufacturers use less carbon disulphid, still there are also some striking pictures of this form of poisoning in English literature. Carbon disulphid is used far less in American rubber manufacture because the ordinary method of vulcanization in the United States depends on the incorporation of sulphur flowers by the aid of heat. (See Chapter 36.)

Carbon disulphid is said to have been first discovered by Lampadius (1) of Freiburg in 1796. It was recommended as a remedy for a great variety of diseases and was actually used in medicine more or less during the following half century, but its real value lay in the property of dissolving fats and such substances as gutta-percha, rubber, and sulphur. Because of this it is very useful as a solvent for sulphur monochlorid, S_2Cl_2 , which is used in vulcanizing rubber by the so-called cold or acid cure. The disadvantages attended with its use lie in its highly inflammable character and its toxicity. It is volatile at ordinary room temperature and its vapors are decidedly heavier than air. The odor is heavy and sweet, somewhat reminiscent of chloroform. It is used in rubber manufacture as a vehicle for sulphur monochlorid, but since the latter is apparently non-toxic, producing no effect on animals except a slight injection of the mucous membranes, the toxic effects of the mixture must be attributed to the carbon disulphid.

This compound had been used for some time in industry before a French writer, Payen (2), in 1851, first called attention to the danger to rubber workers who were exposed to it. Five years later another Frenchman, Delpech (3), gave a description of chronic disulphid poisoning which is still classical. The first industrial case in Germany, according to Harmson (4), was reported in 1866, but it was not until twenty years later that much was written on the subject in Germany. Since then Mendel (5), Stadelmann (6), Koester (7), Laudenheimer (8), Harmson, and others have published studies of the mental and nervous disorders resulting from carbon disulphid poisoning, and Laudenheimer calls this the typical disease of rubber workers. In England, Frost (9) wrote, in 1886, of an earlier investigation which had been made in rubber factories

and in which 33 cases of nervous and mental derangement were recorded, 24 of them involving some affection of the optic nerve.

Lehmann (10) subjected carbon disulphid to careful tests in 1894. According to him, the effect on animals is not locally irritating, but is confined to the central nervous system. Usually in human beings a stage of excitement followed by paralysis is described, but Lehmann does not find this in animals. At first they become stupid and somnolent, then there is twitching of muscles, staggering and vomiting, and finally paralysis, affecting respiration also, and then death ensues. Lehmann then experimented with measured quantities on two of his assistants. Neither of them found that he grew accustomed to the fumes, but rather that his sensitiveness increased. There was some irritation of the pharynx and inclination to cough, aching and burning of the eyes, then increasing headache with a sense of heat in the head, and the pain was increased by any physical or mental effort. They became dazed and confused, the easiest task seemed almost impossible, the gait was uncertain, wandering, there was dizziness, nausea and inclination to vomit, disturbance of sensation, formication, and a feeling that the "hands belonged to someone else." If the exposure was prolonged the symptoms did not pass over on leaving the fumes, but lasted until the next day or even longer. The limits of safety and danger are calculated on the assumption that workmen will be employed only a few hours in a given atmosphere and not more than twice a week.

If the amount of CS_2 in the air is from 1 to 1.2 mg. per liter, or one part to 1,000,000, headache and dullness or confusion will come on in a few hours; with 1.5 to 1.6 mg., headache comes on in half an hour; with 2.5 mg., headache comes on immediately and lasts many hours, even if the exposure is over in less than two hours; with 3.5 mg., there are severe symptoms and unconsciousness comes on after half an hour; and the same is true of amounts as high as 7 or even 10 mg.,—the only difference being a very slow recovery after such exposure.

According to Harmson only two acute and fatal cases are reported in the literature. Both were in men, one of whom was cleaning a reservoir, the other, cleaning a pump through which CS_2 was delivered. Industrial poisoning is practically always chronic, and tragic pictures are drawn by the earlier writers of the severer forms of this chronic intoxication. Thus, Delpech, writing in 1863, says that rubber workers, after showing all the manifestations of excessive exaltation of the nervous system, fall into an increasing state of general breakdown, and at the end of several years' work are degenerated both morally and physically, and are quite incapable of making a living any longer.

In England the report of the departmental committee on dangerous trades states that some years before, functional nervous derange-

ments, paralysis, and insanity, were not at all uncommon among girl vulcanizers, and also among men vulcanizers. All the workers of this class who appeared as witnesses before the committee had been ill, and among the severe cases were two men who had lost the use of their legs completely for about a fortnight and had recovered very slowly. A girl vulcanizer had attacks of uncontrollable excitement, in the intervals between which she would sit in a dull stupor crouching over the fire, and had to be carried to bed. Another girl lost the use of her fingers and partly of her legs, walking slowly and laboriously. Oliver (11) even spoke of a factory in which the windows of the vulcanizing room had been barred to keep acutely poisoned men from leaping out during attacks of mania.

Recent literature does not yield such extreme cases, the usual form now encountered being either a rapidly developing insanity or a polyneuritis with more or less paralysis. Laudenheimer collected the histories of no less than 50 cases of carbon disulphid insanity which were treated in Flechsig's clinic in Leipzig. The early symptoms in these cases consisted usually of frontal headache, dizziness, increasing weariness and loss of strength, transient excitement, and slight delirium, very like alcoholic intoxication. Later deep depression came on; then, if the exposure continued, an increasing indifference, apathy, or melancholy, and always a weakened memory developed. Drowsiness and stupidity would then sometimes pass suddenly into acute mania, or into melancholia with delusions of persecution. These might terminate in recovery or end in incurable dementia. Such cases usually developed during the first weeks or months of work.

The other type of poisoning has a slower onset and is characterized by an increasing sense of weariness and weakness, especially in the legs, a sense of numbness and coldness in the feet, pains in the joints, and atrophy of the muscles. It is a toxic polyneuritis (Harrison (4), Schroeder (12)) which may involve any of the nerves. In one of Koester's (7) cases there was atrophy of the interosseous muscles and the muscles of the ball of the thumb, together with loss of sensation, so that a deep pin prick was felt as a touch; and there was a loss of strength so that the right hand recorded only twenty on the dynamometer, while the left recorded eighty. Guillaïn and Courtellement (13) saw a girl of 17 years, a maker of toy balloons, who had a polyneuritis involving all four extremities, with paralysis and atrophy, but with no sensory disturbance. She had also a loss of memory.

The appetite is at first increased and the sense of well-being is marked during the early stage. The spirits may even be hilarious, but the stage of depression soon follows with throbbing headache and general wretchedness. Koester publishes the histories of four typical cases in young women vulcanizers, the second of which reads as

follows: "A girl of 23 years had worked for two years dipping rubber bathing caps in a vulcanizing solution for four hours a day. Her illness began with a feeling of weakness and of great weariness, especially in the legs, so that walking was increasingly difficult; she had also headache. When she was examined it was found that the patellar reflex was diminished, the peroneal muscles very weak so that the feet hung limp, and there was loss of electric excitability. She could hardly raise her feet from the floor and her toes dropped as she did so. Improvement followed when she left the factory, but later on she went back to work and the symptoms returned. She began to stumble and fall; her feet felt cold; she complained of throbbing headache and of frequent and imperative micturition, there was loss of sensibility in the fingers of the right hand and in both feet."

Koester says that carbon disulphid poisoning is as varied in its manifestations as lead or alcohol. Probably because of this and because so many of the victims are young girls, certain French authors, under the leadership of Pierre Marie (14), hold that carbon disulphid is not a primary cause of nervous derangement but only the exciting cause (the "agent provocateur") of hysteria in people who are already predisposed to it, and an industrial disease only in the sense that traumatic hysteria may be. (See Guinon (15), also Marandon de Montyel (16).) On the other hand, Koester claims to have found degenerative changes—cloudy swelling, fatty degeneration, and sclerosis—in the brain cells and in the cells of the spinal ganglia as a result of repeated inhalations of CS_2 , and Quensel (17), who made an autopsy on a case of acute delirium, found severe diffused changes in the cerebral cortex and in the ganglion cells.

Loss of vision, which is, according to Birch-Hirschfeld (18), in all probability due to primary changes in the optic nerve, not in the retina, has been described in industrial CS_2 poisoning. Thus Terrien (19) in 1920 reported two cases of central scotoma, with notable reduction of the visual field in persons who had been exposed to vapors of CS_2 throughout an eight hour day while spreading a solution of rubber in benzine and carbon disulphid on paper to make mustard plasters. A retrobulbar neuritis was found, similar to that seen in alcohol and in nicotine poisoning. Haas and Heim (20) have had opportunity to examine many cases of chronic poisoning in Parisian rubber factories and devoted special attention to the eye in these workers. They find that local irritation is slight, but a prolonged absorption of the vapors sets up a toxic amblyopia which is favored by alcoholism in the men rubber workers, and by the extreme poverty of the women.

Heath (21) of Indianapolis saw carbon disulphid poisoning in a woman who had been exposed to fumes,—not very heavy,—and had

been obliged to quit work because of her increasing nervousness, irritability, insomnia, weakness of muscles, and emaciation. She came to Health complaining of a mist before the eyes and although at the time her vision seemed normal, when he examined her some months later her general condition had improved very much, but the loss of vision was very marked and was not improved by glasses.

Constensoux and Heim (22) presented at the International Congress of Industrial Hygiene in 1910 the results of a study they had made of men and women who were not suffering from severe carbon disulphid poisoning, but were at the time employed in work exposing them to it. They gave special attention to the neuropathological signs of intoxication. They found that in workshops where the air contained from one to one and a half grams of carbon disulphid in a cubic meter, 82 per cent of the employees had a history of headache, vertigo, depression of spirits or intellectual torpor, or simply irritability and impatience at the end of the day's work. One of them had suffered so much cerebral impairment as to be forced to quit work. Another had every sign of a "polyneuritic psychosis." Seventy-eight per cent of this same group had sensory and motor symptoms of a diffuse polyneuritis, especially of the legs, which in three instances presented the clinical picture of pseudotabes, with scattered pareses, pains, and motor incoördination. Seventy-seven per cent had disturbance of vision, sometimes very marked. In three per cent there was a decided diminution of visual acuity and color sense and a narrowing of the visual field. Sixty-two per cent had loss of appetite, dyspepsia, sometimes nausea and vomiting, at the end of the day's work, and 54 per cent had weakening of the sexual functions.

In contrast to these disturbances, the effects of which were sometimes still present and which had always necessitated at least a temporary absence from work, were the histories of persons who worked in shops where the carbon disulphid did not exceed 0.218 gm. per cubic meter of air. There were nervous and psychic symptoms among these workers also, but of a much slighter character.

Carbon Disulphid in Industry.—The chief use of carbon disulphid in industry is in the vulcanization of rubber where it is used as a solvent for sulphur monochlorid (S_2Cl_2) which latter is, according to Lehmann (10), practically harmless. This method of vulcanization, or incorporation of sulphur in rubber, is much more generally used in France and in Germany than in England, and more in England than in the United States. One of the reports of the German Factory Inspection Service, issued just before the war, states that a certain rubber factory in Prussia had recently introduced a vulcanizing machine which would displace 150 women vulcanizers. I had just finished an investigation of 35 American rubber factories employing more than 100,000 persons and had not found altogether 150 persons engaged in carbon disulphid vulcani-

zation. Laudenheimer (8) says that in Leipzig, in 1897, 265 out of 758 rubber workers were exposed to this poison through inhalation and through direct contact, and that this figure did not represent the whole truth; for the workers were very shifting and in one place 460 had to be employed in one year to keep up a force of 120.

Bacquias (23), in France, writes of headache, dizziness, excitability, causeless laughing or crying, or fits of anger followed by depression, fatigue, and insomnia, all resulting from the work of vulcanizing rubber with carbon disulphid. Briau (24) was puzzled to discover that in a certain foundry in Lyons there was a most unusual amount of mental breakdown among the workmen. Within a short time 8 out of a group of 30 men had symptoms varying in severity from mere overexcitement to pronounced mental disease. Two men were maniacal for four days and one was in a state of deep hebeticism with loss of memory and hallucinations. The others were excited, nervous, and had morbid eccentric ideas, or sudden change of character with impulsiveness and a loss of capacity for work. Only the first failed to recover. Investigation showed that these men were employed in repairing machine belting and had to use carbon disulphid in fastening rubber strips on the leather belting. There had been no cases of mental disturbance before the year that this repair work was introduced. This is practically the same sort of work as the making of rubber and leather horseshoe pads in our country.

In 1908, T. M. Legge (25) examined 19 workpeople who were exposed to the fumes of carbon disulphid from goods which had been treated with it and hung up to dry outside the range of the exhaust ventilation provided for these fumes. He found muscular tremors in four, while seven were cachectic in appearance, and two had slight weakening of the grasp.

Vulcanization by means of carbon disulphid with sulphur monochlorid is known to the trade as the "acid cure" or the "vapor cure." It is used in the American rubber industry only to splice the inner tubes of tires, and to vulcanize dipped rubber goods—such as surgical gloves, toy balloons, bathing caps, finger cots, and, more rarely, hot water bottles and nipples, and also thin sheeting for rubber dam and cheap rubber clothing. Inner tubes are painted with it; very thin goods are hung in a vapor chamber; and heavier goods are dipped in it,—the last method being, of course, attended with the greatest amount of exposure.

The cases of carbon disulphid poisoning reported in this country from the rubber industry are not many. The earliest ones are described by Peterson (26) in the *Boston Medical and Surgical Journal* for 1892, but the cases occurred in 1887. Peterson waited several years before publishing, in the hope of being able to add to the number, but he then gave up, baffled by the difficulty of getting past

the secrecy that surrounds many factories in which dangerous compounds are used. These cases of Peterson's, three in all, came from a rubber factory near New York City and the men were all sent to the Hudson River State Hospital for the Insane, suffering from acute mania. The second was not entirely irrational; in fact, he could control himself to a great degree and could give a perfectly rational account of his work and its effects. All had been exposed to carbon disulphid; all were young men between 23 and 31 years; and, according to the story of the second, some five or six other men had gone insane from the same work. The acute mania subsided after a few weeks to be succeeded by increasing dementia, then by slow recovery. One man was discharged after 18 months as cured, the second, after 13 months; and the third, after two months. The second case, the mildest, had the hysterical symptoms described by Marie (14), who always insisted that carbon disulphid is only the exciting cause of hysteria in persons already predisposed to it. The patient had terrible dreams; he was depressed and melancholy, believing at times that he had lost his lungs and his tongue; his memory was impaired; and he had muscular tremors. He said, as have most such cases, that the first effect of the fumes was to make him hilarious and talkative, then depressed.

Heath's (21) case was from an Indianapolis rubber factory, in a woman who was employed in splicing the inner tubes of automobile tires with carbon disulphid. I was told of a case of sudden acute mania in a man who did similar work in a Detroit factory and who recovered but never returned to the atmosphere of carbon disulphid.

In the course of my investigation of the rubber industry in 1914 I secured a number of histories of carbon disulphid poisoning, not from physicians; for apparently they did not know of this particular danger in rubber manufacture, but from the men in the industry. One was an American rubber worker who, for the preceding year, had been employed in dipping rubber goods in a bath of carbon disulphid, and who suffered from nervousness, loss of appetite, increasing muscular weakness, and attacks of dizziness. He was still working at the time. Another was splicing inner tubes and had been doing this work for three years. He was, of course, exposed to much less carbon disulphid vapor than the former; for he simply painted the fluid over the ends of the tire. He complained of indigestion, attacks of vomiting, loss of appetite, burning of the eyes, and a feeling of weakness. He was obliged to quit work every now and then on account of illness.

The foreman of the cold-curing department of a dipped-goods factory was very eloquent to me on the subject of carbon disulphid poisoning. He said his men used to go crazy from the fumes until he made them work for short spells only, alternating with other work. During the preceding year he had had 12 men under him and all

had felt the effects in some way, complaining of headache and dizziness, or indigestion, or loss of mental power, or loss of memory, or muscular weakness, especially in the legs. He himself suffered a good deal from dizziness and severe occipital headache, and had lost strength. He said he always felt the effects of the fumes most at the beginning of the week or after a vacation. Sleeplessness was one of his chief complaints, while one of his workmen said that the fumes made him so drowsy all the time that he could drop off to sleep whenever he sat down.

The fumes in this particular dipping room were very imperfectly carried off by feeble exhausts. Three of the men who had worked there during the year preceding had had pronounced nervous symptoms. One became partly paralyzed after 18 months' work. His legs were weak, though he managed to get about the house; but his arms were so helpless that his wife had to dress him and feed him. This condition lasted for months. A second man had been at work only one month when he began to get excited without cause and to talk foolishly, wanting to argue about irrelevant subjects. The foreman, familiar with these symptoms, was alarmed and advised him to quit, which he did, and he recovered. The third man also had worked only a month when he showed signs of mental disturbance. He was a Hungarian who spoke no English, and the foreman did not recognize his condition until he became very much excited and unmanageable. He was sent home, and his wife reported that he acted so strangely and was so uncontrollable that she took him to a doctor. When the latter asked him about his work he told a long rambling tale of lumbering down the river, and could not be convinced that he had ever worked in a rubber factory. The foreman thought he had recovered, but he never came back to the factory. These last three cases bear out the statement of Laubenheimer that a carbon disulphid psychosis develops after a very short exposure to the poison, while cases of paralysis require a longer exposure.

The second industry in which carbon disulphid is extensively used is in the making of artificial silk by the so-called "viscose" process. For this, cellulose, usually in the form of wood fiber, is treated with caustic soda and sodium sulphid, which change it to alkali-cellulose, an addition product. Then further treatment with carbon disulphid changes this to cellulose-xanthate, which also is an addition product. It is a deep orange-brown, in consistency like gutta-percha. A lump broken off will give out a little odor of CS_2 . The xanthate is spun under a 10 per cent solution of sulphuric acid with sodium sulphate,* cellulose hydrate results, and the hydrate group is lost in drying. There may be a slight excess of CS_2 , in which case a little is given off in the first stages of spinning; but the chief point of danger is in the formation of the xanthate, the escape of fumes when the vats are

* A little hydrogen sulphid is liberated at this stage. See Chapter 26.

opened, and the exposure to fumes when the vats must be cleaned. Another common danger is from leaking pipes; for carbon disulphid dissolves linseed oil and if pipe joints are wiped with white lead in linseed oil and not given time enough to set properly before the CS_2 is run in, they will spring leaks.

In 1904, Jump and Cruice (27) of the University of Pennsylvania published an interesting article on carbon disulphid poisoning in an artificial silk works. The history of one of their patients is so typical that it is worth quoting. In this factory, at the completion of the xanthate reaction, the CS_2 is driven out by a blast of air, but not all is got rid of, and when the contents of the vat are dumped, quite a little fume escapes, and even more fumes are encountered in cleaning the vats. The first patient seen by Jump and Cruice said that when he would go to work in the morning he would feel exhilarated and jolly, though when the fumes were thick, as in cleaning a vat, he might almost be overcome and obliged to go out-of-doors. When he got home in the evening he would be morose and irritable, and could eat nothing with appetite because everything tasted of CS_2 . Presently he began to have severe headache, vertigo, weakness first in the arms and then in the legs, until at last he could hardly climb stairs. He had muscular tremors, slight ataxia in the legs, a weakened grip, and he could not get up from his knees without help. His memory and his vision were impaired. The number of red corpuscles was five million, but the hemoglobin was only 40 per cent. He recovered completely when removed from contact with carbon disulphid.

Francine's (28) case also came from an artificial silk works where the man was engaged in the same sort of work, cleaning out the wooden vats which were used for treating the wood fiber. The fumes used to exhilarate him at first, and he felt better than usual; then he began to sleep poorly, lost his appetite, had headache and dizziness, and in the evening would grow very depressed. One night an attack of delirium came on with dizziness, a splitting headache, and air hunger. He was cyanosed and his breathing was slow and labored. He had but 40 per cent hemoglobin, although the red cells numbered 4,200,000.

Dr. Richard Cameron of Buffalo showed me two men with carbon disulphid poisoning in the spring of 1923. Both the men had worked in the treatment room of an artificial silk factory in which the ventilation is unusually good. The first man had been given six weeks complete rest and had just returned, anxious to go back to work. He was a tall gaunt man with a nervous manner, easily excited and irritated by questions, and unable to bear opposition. He had no inclination to exaggerate his disability, rather the contrary for he was keen to work again, although anxious to be given a job where he could sit down. When he was taken ill he had loss of

power in the legs and was very nervous, with a pronounced shaking palsy. His spirits were very depressed, he was drowsy all the time, he could fall asleep at any moment, and slept heavily at night. When we saw him, his legs were still weak and walking was difficult, especially going upstairs. A certain degree of ataxia was evident and he swayed when standing with his eyes closed.

The second man was in a hospital at the time. He had no motor paralysis, but was in a very emotional and nervous state, although trying hard to control himself. He seemed as if about to burst into tears at any moment and suffered keenly from mortification, over his betrayal of weakness, saying "I was all right, doctor, till you came now and stirred me up again." He did not wish to talk about his symptoms but to be left alone. Only unwillingly would he admit that he had been much depressed, and that he slept heavily, but his wife said that he jumped and jerked all night, that he was always drowsy and that latterly he had had queer things happen,—for instance that when he was looking at a thermometer it seemed to leave the wall and came towards him. Suddenly, while talking to us, his self-control gave way and he buried his head in the pillow and burst into tears. Dr. Cameron told me that the acute attack had begun with hallucinations of sight and ideas of persecution and lively fears. Some six months later when I inquired about him he had not fully recovered.

Finally, there is a source of carbon disulphid poisoning in the making of an important accelerator for the vulcanization of rubber, and perhaps in its use. This compound is carbanilid, made, as its name indicates, by the action of CS_2 on anilin oil. One case of severe, rapidly developing intoxication ending in death, has already occurred from the production of this compound, and although following this the processes of manufacture have been strictly safeguarded, we do not know what danger there is from its use.

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CHAPTER 27

CARBON MONOXID. MINE CASES

CARBON MONOXID

CARBON monoxid is the oldest of the industrial poisons; for it must date from man's discovery of the use of fire. Incomplete combustion of carbon, burning in an atmosphere without enough oxygen, results in the production of CO instead of CO_2 and H_2O . This gas, odorless, non-irritating and, therefore, giving no warning of its presence, is responsible for more deaths than all other gases put together, but the greater number of these, in the United States at least, are not of industrial origin but are caused by the accidental or deliberate inhalation of illuminating gas, which in this country commonly contains a high percentage of carbon monoxid.

The literature on carbon monoxid is so voluminous that only a small part of it can be treated in a book such as this, and I have therefore confined myself almost entirely to the more recent publications, especially those from American sources. The reader is referred to the very interesting book by Glaister and Logan "Gas Poisoning in Mining and Other Industries" (Wm. Wood and Co., New York, 1914) for the British experience with industrial carbon monoxid poisoning and its after-effects, and to the very exhaustive study of Lewin of Berlin ("Die Kohlenoxydvergiftung," Berlin, Julius Springer, 1920), for the history, chemistry, toxicology, clinical picture, and industrial sources of carbon monoxid.

The description of carbon monoxid poisoning which follows is taken chiefly from the work of Haldane (1) in England, of Lewin in Germany and of Yandell Henderson (2) and his colleagues and of McNally and Doremus (3) in the United States. Carbon monoxid is almost odorless and has no irritating effect on the lungs, so that in its pure form it gives no warning of danger. It is considered not a true poison; for it seems to be physically and in relation to the tissues of the body, even including the nervous tissues, an entirely inert gas except in a single respect, its power of combining with the hemoglobin of the blood. According to Nicloux (4), the combining power of carbon monoxid and hemoglobin is between 200 and 300 times that of oxygen and hemoglobin. Hill and Barcroft (5) have shown that carbon monoxid enters into combination with hemoglobin more readily when a little oxygen is

present than when it is completely absent, and that more CO will be taken up by unsaturated oxyhemoglobin than by oxygen-free hemoglobin.

The effect produced by carbon monoxid is to be traced, therefore, to the lack of oxygen, and the symptoms are those of anoxemia. Haggard (6) says that death under carbon monoxid asphyxia is due to failure of respiration. There is no direct toxic action of carbon monoxid upon the heart; for if respiratory failure is prevented by means of administration of 8 or 10 per cent carbon dioxid the CO combination with hemoglobin may rise to an unusually high percentage without any evidence of impairment of the heart function. The failure of respiration which occurs in fatal cases is in the nature of a fatal apnea vera. The lack of oxygen resulting from the formation of CO hemoglobin induces excessive breathing, and as a result excessive loss of carbon dioxid and failure of respiration. Then, following respiratory failure, the increased anoxemia from this cause speedily results in the development of heart block through its various stages.

In spite of the avidity with which CO is taken up by hemoglobin, the resulting combination is unstable and the red cells surrender readily the CO which has been taken up so that if the victim of gassing be removed to pure air while still living, the carbon monoxid will disappear from the blood in about one to four hours' time. Nicloux finds that the blood corpuscles, even if they have been saturated with carbon monoxid, are not devitalized at all but are ready to take up their normal function when supplied with oxygen. However, during the period of carbon monoxid asphyxia, injury to certain tissues may occur because of the temporary deprivation of oxygen, the injury being greatest in those cells whose need of oxygen is greatest. This is not, strictly speaking, a toxic action, since, as Henderson says, "It is not retention of carbon monoxid nor any direct action of the gas, but the results of the injury to the brain and other organs due to insufficient oxygen supplied by the blood while the patient was breathing the gas, which is responsible for the prolonged coma and subsequent death or incomplete recovery. There is no known method of restoring tissues to normality after parenchymatous degenerations have once been initiated. Left to itself, nature does all, so far as present knowledge goes, that can be done to stop the abnormal processes. The man recovers completely if the asphyxia has not been too intense and prolonged, although in many cases men who have once been "gassed" exhibit a muscular weakness of the heart permanently thereafter. In more severe cases, the patients recover only with the loss, partial or complete, of vision, power of speech, or with some other nervous defect."

Evidence of injury to the lungs is shown in the fairly large proportion of victims of gassing who have an excess of fluid in the respira-

atory tract, as shown by frothing at the mouth in the early stages, the appearance of râles in the lungs, sometimes pulmonary edema and later broncho-pneumonia.

An investigation was recently made by a commission of physiologists, formed at the request of the American Gas Association, to determine the best method of treating carbon monoxid asphyxia (7). In the course of this study they examined the records of 860 cases of gassing which had been treated in nine hospitals of Boston, New York and Philadelphia, with special reference to the symptoms in the respiratory tract. It was evident that moisture in the respiratory passages was of fairly frequent occurrence in these cases, and although the percentage of pneumonias following gassing is not high, it is clear that a careful examination of the lungs was rarely made in these cases and the fact that there is almost invariably a rise in temperature before death makes it seem probable that some degree of broncho-pneumonia must be present in nearly all patients who do not succumb immediately to the dose of gas. The pneumonia in such instances, however, is probably only a contributory cause of death, the latter being due in the main to cardiac failure and central vasomotor failure.

The members of this Committee make a comparison of their figures with those which W. Gilman Thompson (8) of New York collected in 1904 and those of Lämpe of Dresden, collected for the period between 1912 and 1921. Only patients sufficiently gassed to be unconscious were included in this study, 90 of Thompson's; 205 of Lämpe's, and 514 of the 860 cases collected by the Commission. The mortality in Thompson's cases was 18.8 per cent; in Lämpe's, 17.6 per cent; in the Commission's, 22.6 per cent. The average rate of respiration for these three groups were 30 per minute, 24 to 32, and 28 respectively. The pulse rate of Thompson's patients was usually about 120 but frequently from 136 to 140. In the Commission's series, 51.1 per cent of the patients had a pulse rate below 120; 18.9 per cent over 120; the average pulse rate on admission for all was 104.

Thompson observed an elevation of the temperature in almost all his patients. In eight there was a preliminary fall of temperature. Lämpe reports that in most of his cases the temperature did not rise above 38° C. (100.4° F.), though occasionally it reached 40° C. (104° F.). Of the Commission's patients 17.5 per cent were admitted with a temperature below 97° F.; in 44.2 per cent the admission temperature ranged between 97° and 99°; and in 38.3 per cent the temperature was above 99°.

In discussing the lung findings, Thompson says, "Occasional sequelæ are bronchitis, broncho- and lobar pneumonia." Later he says, "It was a surprise to the writer that broncho-pneumonia, or other definite pulmonary lesion, is not more constantly an outcome

of fatal gas poisoning, but in only three of the twelve autopsies was broncho-pneumonia observed." The lung findings, however, in the twelve autopsies which he reports showed entirely normal lungs in only 25 per cent of the cases. The autopsy findings were as follows: normal, 2 cases; normal, except for a few miliary tubercles, 1 case; congestion (complete), 1 case; congestion and edema (complete), 3 cases; congestion and edema in partial areas, 5 cases; emphysema (partial and compensatory), 4 cases; atelectasis (partial), 2 cases; broncho-pneumonia, 3 cases. There is no mention of physical examinations of the lungs of the patients who recovered, so we have no means of judging the incidence of transient lung changes in Thompson's cases.

Lämpe found bronchitis very often; one case of edema (with frothy sputum); 10 cases of broncho-pneumonia; two cases of pleuritis without broncho-pneumonia; seven of hypostatic pneumonia; four of aspiration pneumonia; and two cases of gangrene of the lungs—a total of 12.7 per cent of cases which showed lung involvement, exclusive of the cases of bronchitis.

Of the Committee's unconscious patients, 20.5 per cent had râles; 7.2 per cent edema; and 9.4 per cent pneumonia—a total of 37.2 per cent with abnormal moisture in the lungs.

The lesions in the central nervous system which have been found after death from gas poisoning (illuminating gas, vapors from burning charcoal, burning wood, industrial gases, etc.), have interested many pathologists, and there is a division of opinion as to the true pathology of these cases, many, especially of the earlier investigators, believing that CO has a primary toxic action on the central nervous system; others, especially the more modern ones, attributing the changes to oxygen deprivation.

Poelchen (9) in 1882 described symmetrical foci of yellow softening measuring 1.5 by 0.5 to 1.0 cm. in the lenticular nucleus of the corpus striatum. According to his researches, the first description of encephalomalacia after CO poisoning was written in 1865 by Klebs for *Virchow's Archiv*, vol. 32. Klebs described five cases in one of which the softening was in the lenticular nucleus. Simon (10) was the next, reporting three cases of CO poisoning in which after apparent recovery death came on suddenly and autopsy revealed, in the first, softening in the cerebral hemisphere, the left corpus striatum and thalamus opticus; in the second, softening in the cerebral hemisphere; and in the third, in the corpus striatum.

In 1892 Koch (see Sibelius (11)) assembled from the literature 18 cases of cerebral softening, Posselt later added two, and Runnberg three. These areas were chiefly in the lenticular nuclei, but in two cases Posselt found softened areas in the pons and cord. Sölder described four in the cerebral cortex, and von Rokitsansky five in the cortex and cord. Sibelius (11), after careful microscopic studies,

concluded that the cerebral pathology of CO poisoning is a disseminated encephalitis, akin to that caused by alcohol, and sometimes complicated with areas of ischemia caused by degenerative changes in the arteries. He agrees with Runnberg and with Kobert that the essential injurious action of CO is not only a driving out of oxygen, but a primary toxic effect on the central nervous system.

In 1914 Kolisko (see Hill and Semerak (12)) said that carbon monoxid invariably produced a characteristic lesion in the brain, namely, bilateral softening of the lenticular nucleus. This statement receives strong confirmation in a paper published in 1918 by Hill and Semerak (12) who had an opportunity to study 32 brains * from fatal cases of carbon monoxid poisoning brought to the Cook County Hospital in Chicago. They found a very general hyperemia of the brain substance and leptomeninges but this was of no diagnostic importance. In 21 specimens there was edema and internal hydrocephalus. In 11 the blood was cherry red, the pink tint sometimes extending to the white matter but four of these were from persons found dead, and five from those dying in a few hours.

In 14 brains a bilateral softening of the lenticular nucleus was evident to the naked eye. Indeed, in extreme cases the place of the nucleus was occupied by a slushy mass. The other 18 cases which were not grossly abnormal were found on microscopic examination to have areas of necrosis in this same region. These latter were from youthful victims without pre-existing vascular degeneration, or victims of an overwhelming dose of gas which killed quickly. The degree of damage to the lenticular nucleus depends on the age of the patient, the degeneration of the vascular system, pre-existing disease of the brain, the duration of life after the accident and the amount of gas inhaled. Hill and Semerak find, therefore, that carbon monoxid poisoning produces a characteristic lesion of the brain, namely, a bilateral ischemic necrosis of the lenticular nucleus, especially the globus pallidus. This lesion results from a vascular disturbance brought about by the presence of carbon monoxid in the circulating blood which produces a thrombosis with degeneration of the vessel walls. Anatomic peculiarities in the circulation account for the localization of the lesions in this region. The necrosis varies from slight perivascular lesions in the globus pallidus to grossly visible softening of the entire lenticular nucleus and the internal capsule.

Hill and Semerak find spontaneous hemorrhages in the leptomeninges and punctiform hemorrhages throughout the white matter of the brain. Another frequent finding is hyperemia and edema of

* These were examined fresh, then hardened in 10 per cent dilution of formaldehyd, and sections hardened cautiously in alcohol beginning with 20 per cent, embedded in paraffin, stained with hematoxylin and eosin, with phosphotungstic acid hematoxylin, van Gieson's toluidin blue, Weigert's stain, Marchi's osmic acid, Sudan III, and Ciaccio's stain.

the brain with internal hydrocephalus. The nerve cells, however, have a high degree of tolerance to the poisonous action of carbon monoxid. They do not believe that cerebral arteriosclerosis can be attributed to CO, but probably it increases the vulnerability of the individual to small amounts of gas. Their studies emphasize the relation between carbon monoxid poisoning and the subsequent development of nervous and mental disease. The diagnosis of carbon monoxid poisoning as a cause of death depends on changes in the lenticular nucleus which will be found after the characteristic color of the blood has disappeared and the time for detection of CO in the body is past.

Other studies have been published recently, concerning the changes in the central nervous system after death from CO poisoning. Legry and Lermoyez (13) found bloody spinal fluid in the body of a man who had a history of cerebrospinal meningitis during the war and twice had suffered concussion with loss of consciousness. They believe, however, that such a hemorrhage is unusual and was due to the special vulnerability to gas of the nervous system in this case. Hedinger (14) reported a case of extensive intravital clotting of the blood in a man who died suddenly less than 24 hours after inhaling the gas, and Garnier and Cathala (15) found inflammation of terminal arteries causing patches of gangrene as a sequence of fatal CO poisoning.

The view that CO has a direct toxic action on the nervous system is denied by Balthazard (16) who holds that the degenerative changes reported are arti-facts and that all the manifestations following gassing can best be explained as the result of oxygen starvation. This view is strengthened by the work of Haggard (17) on the growth of the neuroblasts in the presence of carbon monoxid, although he is careful to state that his observation must not be interpreted as weighing against the view that the toxicity of illuminating gas on the entire organism is due to the carbon monoxid and the asphyxia which it produces. Haggard showed by experiments on growing neuroblasts in vitro that carbon monoxid by itself has no injurious effect upon growing nerve cells even in a concentration of 79 per cent. It is in this respect as neutral as nitrogen. Illuminating gas, however, contains in addition to CO another toxic substance, for it is poisonous to neuroblast cultures in a concentration as low as 0.1 per cent. (See page 396.)

Forbes, Cobb and Fremont-Smith (18) experimenting with cats and dogs found that carbon monoxid asphyxia causes a rise in intracranial pressure, which has two phases, the first occurring during asphyxia and caused by congestion due to a rise in arterial pressure; the second after asphyxia, caused by edema, probably. This intracranial pressure is of sufficient height to produce transient eye ground changes observable by ophthalmoscope. The increase in

brain bulk was observed through a trephine opening and it persisted after decapitation of the animal, showing that it was a true increase in volume, and it was reduced by intravenous injection of hypertonic saline solution which is known to cause absorption of water by the blood from the tissues.

Only one human case came under their observation and treatment, but it was significant. A man 25 years old who had been overcome by gas from a leaky gas heater, was taken to the Boston City Hospital, unconscious. Two hours later, while still unconscious a lumbar puncture was made, the spinal fluid pressure was 21 mm. of mercury (the normal being from 8 to 15 mm). There was a temporary fall, resulting from the removal of 50 c.c. of fluid and the patient became more active and restless, but at the end of 22 hours he was still stuporous, and when aroused complained of headache. Another lumbar puncture was made which showed a pressure of 19 mm. Then 100 c.c. of 15 per cent salt solution was given intravenously during a period of 18 minutes. Immediately after, the patient became clearer mentally and said that his headache which had been severe had entirely disappeared. He responded readily to questions and during the next few hours sat up and took food. The relief following injection of the salt solution was immediate and lasting whereas that following withdrawal of spinal fluid was slight and temporary.

The literature of gas poisoning is full of histories of symptoms of all kinds following recovery from gassing, especially with illuminating gas, but also with industrial gases and gases produced by explosions in mines. For such cases the reader is referred to Glaister and Logan and to Lewin who says that there is no known poison, the effects of which are so varied and so widespread as carbon monoxid. The most commonly noted effects are mental changes, sometimes accompanied by paralyses. Briand (19) declares that loss of memory is common as a result of CO poisoning. It is not slow and progressive as in alcoholic dementia but comes on suddenly usually wiping out the events following the accident but sometimes also the memory of past life. Oliver (20) has seen blast furnace men after gassing, when the immediate symptoms have disappeared, develop incomplete loss of power in the limbs and later an affection of speech. One man was left with a slow and stepping gait and a feeble hand grasp, and nystagmus, and there was little change in his condition at the end of two years. Other men pass through periods of exaltation like toxic hysteria.

Gowers' (21) case, reported in 1908 and attributed to the vapors of petroleum, is probably an instance of CO poisoning. Gowers called it pseudomyasthenia of toxic origin. The man was testing gasoline motors indoors. His symptoms developed rapidly, cleared up when he quit his job, and recurred when he came back. For six

months he suffered from disturbance of the sense of taste (sweets seemed salty), then a sense of constriction in swallowing which increased till he could take only soups and jellies, but there was no regurgitation. His voice was easily exhausted, especially for consonants, and he could not whistle. He was easily exhausted in walking, and there was weakness of the muscles of the eyelids but the reflexes were normal and so was the electric excitability.

The most carefully studied instances of such after-effects of carbon monoxid poisoning in American literature are not industrial in origin but come from exposure to illuminating gas or to the exhaust gases in garages, probably because the victims of such accidents are often educated men, not infrequently physicians, who are able to describe their own mental symptoms clearly and who are attended by scientifically trained physicians (see Hitchcock (22), O'Malley (23)). One of the few instances in American literature of industrial poisoning from carbon monoxid gas with serious after-effects is recounted by Brose (24). He saw in consultation two cases of blindness following an accidental gassing in a well which was in course of excavation by dynamite.* The man who owned the farm let himself down into the well shortly after a discharge of dynamite and soon fell in a faint at the bottom and it was about twenty-five minutes before he could be brought up to the surface. His rescuer was exposed to the gas for a shorter time and not at the bottom of the well. The first man suffered from blindness and loss of memory for months, the second was blind for 32 hours, and his memory was affected for several days. Both eventually recovered.

Toxic paralysis of the left axillary nerve developed several days after resuscitation from gassing in a case reported by Mendel (25) and lasted several weeks. Abelsdorff (26) saw a case of temporary blindness with paralysis of the eye muscles which appeared on the fourth day after gassing with carbon monoxid. At the end of four weeks the paralysis had cleared up and vision was normal.

The case reported recently by Krauss resembles Gowers', for it was the result not of a single gassing but of prolonged exposure to the fumes from a gas engine (27). This man, who was treated in Bellevue Hospital, had worked from August, 1920, to June, 1921. In February, 1921, he began to suffer from dizziness, occasional nausea, frontal headache, and general malaise. His legs grew gradually weaker until in April he was unable to walk and he had sensations of numbness and coldness in the legs, hands and forearms. There was loss of sensation in the legs almost to the knees, and in the toes a slight defect in the sense of position. The cranial nerves were all normal. Negative results were obtained from six Wassermann tests of the blood and three of the spinal fluid. The

* For the composition of such gases, see page 390.

most striking symptom was a marked atrophy of all extremities.* Later Krauss saw a similar case also caused by carbon monoxid which did not however show such profound muscular atrophy.

Haldane says that in a normal man at rest the tissues consume only a little over one-third of the oxygen the blood brings them, while in muscular exertion about two-thirds are used. Therefore, the blood of a man at rest may become nearly one-third saturated with CO without his realizing that anything is wrong, but if he has to make any considerable exertion the fraction of his hemoglobin uncombined with carbon monoxid may not be enough to transport the necessary oxygen and he is liable to collapse. If the blood be more than half saturated he may collapse even at rest, and if he remain a considerable time in this condition the cells of the central nervous system and perhaps the cells of other organs are injured by the lack of oxygen, anoxemia, and unconsciousness is the immediate effect while paralysis or insanity may follow later.

Henderson estimates that usually a man will die who has breathed two parts per 1,000 of carbon monoxid mixed with otherwise normal air for four or five hours, or four parts for one hour. After an explosion of coal dust in a mine there may be from 20 to 50 parts per 1,000 in the air. The blast furnace gas of steel mills runs usually from 250 to 280 parts per 1,000. Therefore, in a mine accident or as a result of an accidental leakage in the pipes from a steel blast furnace a few breaths may be enough to nearly saturate the blood with carbon monoxid, and death follow as quickly as in drowning. High temperature and humidity bring about a more rapid combination of CO with hemoglobin than occurs under normal conditions of temperature and humidity according to Sayers, Meriwether and Yant of the U. S. Public Health Service.

When the amount in the air is not more than one part per thousand a man at rest can breathe it for two hours and a half before the blood takes up as much as 50 per cent. Vale (28) of the Birmingham Mining Research Laboratory in England subjected himself to the influence of measured amounts of carbon monoxid in a closed chamber. Two sets of experiments were carried out, one resting, the other performing five thousand foot-pounds of work per minute on a Martin's ergometer. His conclusions were : 1. Where no work is undertaken in atmospheres containing carbon monoxid up to 1.14 per thousand, 50 per cent of the amount inhaled is the maximum that will be absorbed. 2. Where work is undertaken, the respiration is increased in frequency and the actual amount of carbon monoxid may be from two to four times as much as when at rest. In mining accidents the victim, if he remains at rest and is rescued without having to exert himself, may escape serious damage, but if even at

* Krauss is uncertain whether to attribute the symptoms to CO or to gasoline fumes.

this low concentration of gas, 1.14 per thousand, he makes great exertions to escape he may lose consciousness. It has happened in mine accidents that members of the rescuing party have suffered more severely than the men they came to save because they were working hard while the latter were sitting still. With two parts of carbon monoxid to 1,000 parts of air utter powerlessness and unconsciousness come on and three parts means death unless rescue is fairly prompt.

Nieloux (29) maintains that a large proportion of the hemoglobin may be saturated with CO without fatal result. In a case which he describes, 75 minutes after the poisoning and after 650 liters of oxygen had been administered, the blood still contained 9.08 per cent carbon monoxid, showing that 41.3 per cent of the hemoglobin was saturated with it. The oxygen was pushed and in about an hour this percentage was only 25.4 and four hours later 8.3. The survival of the patient after apparent death for 25 minutes shows that even 9.08 per cent of carbon monoxid in the blood is not fatal. Nieloux is convinced that in those cases on record in which death occurred with poisoning of 0.1 or 0.3 or even 0.4 per cent, some other factor than the CO was responsible for the fatality. The slightest movement is liable to bring on vertigo and relapse into unconsciousness. This occurred twice in Nieloux' case, the man saying he felt well and wanted to go home and then fainting when he tried to get up.

It is of great practical importance to determine the safety limits of carbon monoxid in air which must be breathed over an appreciable length of time by workmen and others, not accidentally but as a more or less daily experience.

Haldane in an extensive investigation of the air of the London underground railways, made in 1896, established a standard for the carbon monoxid content of the air, at 0.1 per cent per 1,000 of air. Henderson and his colleagues, who took up the same problem for the New York and New Jersey vehicular tunnel, put the limit at 0.4 per 1,000, of complete safety from discomfort, but this was to apply only to passengers making the transit of the tunnel in less than one hour. They found that if men are doing hard work they will begin to be unfavorably affected when the concentration of CO reaches 0.6 per 1,000, and in those at rest, as passengers in motor cars, there is risk of considerable discomfort at 0.8 to 1.0 per 1,000 if breathed for as long as one hour.

Henderson suggests the following general rule to apply to periods of not more than a few hours: When the time is measured in hours and the concentration of carbon monoxid is expressed in parts in 10,000 of air, the physiologic effects may be defined by the equations:

- Time \times concentration = 3, no perceptible effect.
- Time \times concentration = 6, a just perceptible effect.
- Time \times concentration = 9, headache and nausea.
- Time \times concentration = 15, dangerous.

Acute CO Poisoning.—The onset of symptoms may be as sudden as a stroke of lightning. This is more likely to be true in men working at blast furnaces or using producer or power gas, but it has also happened in mine accidents that the dead men are found sitting in natural positions, perhaps with their lunch in their hands or with their picks as if they had just paused in their work. Usually, even in exposure to a fairly high percentage of the gas, the man has some warning, such as pressure and throbbing in the head, a feeling of the knees caving in, blurred sight, roaring in the ears. Others note a feeling of dryness and constriction in the throat or sweetish taste or nausea or pain in the stomach. Glaister says that coal miners have told him of a feeling of weakness in the legs which warned them that they ought to leave the mine, but the gas had so dulled their minds that they kept on working mechanically till they fainted. A classical description of this sort of effect is that given by Sir Clement LeNeve Foster who was severely gassed while engaged in rescue work in the great Snaefell mine disaster. He wrote, "I suddenly felt decidedly queer, took out my little brandy flask, but already my fingers seemed incapable of opening it. Everything seemed to be in a whirl. There seemed to be a dense white fog. The foot of the ladder was quite near, but none of us made an effort to reach it." When he found that he was losing consciousness he wrote a farewell letter to his wife in which he would repeat certain words, even whole sentences, again and again. The general sensation, he said, was like a bad dream, and yet he was able to reason properly and to write intelligibly though in a disjointed fashion.

Apfelfbach (30) of Chicago observed some 300 cases of industrial gas poisoning and found that in about one-third of the cases there were no warning symptoms at all, but these were men working in the steel mills and the gas to which they were exposed is much richer in CO than that which would be encountered in any but a very unusual mine disaster. According to many authorities, in carbon monoxid coma the lips should be rosy red and there should be an appearance of perfect health, but in industrial poisoning this seems to be rarely true. Apfelfbach says that the men are usually pale or livid, with blue lips and red blotches on the skin, or even actual hemorrhages under the skin. Loss of consciousness is not complete as often as is supposed; at least among steel workers. There were only 65 cases of typical coma in his 261 cases of gassing in steel workers. The others had only stupor or mental confusion. Glaister also says that there is deeper coma in men who are gradually poisoned by gas in mines or by producer gas than in steel men who are suddenly exposed to enormous doses.

One of the physicians of the United States Steel Company with 17 years' experience in the treatment of gassing in steel workers described to me a typical case, such as he has seen hundreds of

times. If the gassing is severe, the man arrives at the hospital (usually not more than twenty minutes after the accident has occurred) unconscious, with stertorous respiration, rapid and deep, his face not cyanosed or only slightly so, his pulse 80 to 120, neither weak nor bounding. Unconsciousness usually lasts from two to eight hours. He has never seen a man die of gassing. If he is not killed on the spot he recovers and he needs no treatment except removal from the gas. In some cases he passes from unconsciousness into violent, maniacal delirium in which he struggles and seems to have hallucinations. This stage lasts from fifteen minutes to an hour and with it go vomiting and rectal incontinence. Sleep follows this, but sometimes has to be induced by morphin. The man awakens after two to eight hours with a severe headache persisting several hours but with no other symptom. Then for about twenty-four hours he complains of weariness and lassitude, but after that he goes back to work. The worst cases are out only 72 hours and none show any after effects.

Less severe cases reach the hospital in the stage of delirium, the stage of unconsciousness having already passed. A third class, still milder but requiring the ambulance and hospital care, cannot walk alone, are as if drunk, cannot guide themselves, complain of dizziness and headache and nausea, but these men usually do not stay in the hospital over night.

According to Glaister the course of the poisoning determines the after effects. Slow gradual gassing causes much more severe permanent damage than does more rapid poisoning, even though the latter may be accompanied by coma and convulsions. He believes that it is the victims of gradual gassing in coal mines and garages who are most likely to develop pneumonia, weakness of the heart, paralysis, and mental disease, not the victims of sudden gassing at blast furnaces.

A man who recovers from a fairly severe gassing suffers from a throbbing headache, a feeling of constriction in his temples, or a feeling as if his head would split. He is dizzy, his muscles are powerless, so that he may not be able to walk or even hold up his head. Sometimes there is loss of sensation, and men who have been burned in a mine explosion may not feel the pain of the burn after they regain consciousness; they are often cold, shivering, they suffer from palpitation of the heart, and exertion may bring on an attack of cardiac weakness.

An unusual clinical history was published recently by d'Alessio (31) of Naples. A workman who was making connections in gas pipes in an excavation about 80 cm. deep was obliged to quit work because of dizziness, difficulty in breathing, clouding of vision, and general malaise. Following the rule of the company, he was taken home and told not to come back till the next day. He felt better

for a while, ate his dinner as usual, then suddenly in the afternoon the symptoms returned with great severity and he was dead in two hours. Suspicions of criminal poisoning were aroused and a careful autopsy with chemical tests was made, but no change was noted except pulmonary congestion. The presence of carbon monoxid-hemoglobin was demonstrated by spectroscopic examination and by the methods of Hoppe-Seyler, of Jolenisch, of Rubner, and of Katajama, and this although the examination was not made till four days after death.

Egdahl (32) has just published a study of the presence of carbon monoxid in various workshops of the department of mechanical engineering of the University of North Dakota, the amounts being determined by the iodine pentoxid method. They are as follows *:

1. Large Repair Garage: No motors running for the last six hours.
2 to 3 parts per 1000.
2. Gas Engine Laboratory: 2 to 3 parts per 1000.
3. Large Boiler Room: Using coal for fuel. 2 per 1000.
4. Forge Shop: Before starting the ventilating fans, 4 parts per 1000.
After starting the ventilating fans, 2 parts per 1000.
5. Laboratory: After using 6 Bunsen burners 2 hours, 1 part per 1000.

Egdahl made blood counts on 6 men whom he suspected of suffering from chronic CO poisoning. In three the red cell count was over six million, and the eosinophils made up five per cent of the white cell count. The other three had a red cell count between 5,600,000 and 5,950,000, but a normal eosinophil count. He believes that the finding of a polycythemia together with eosinophilia is very significant of CO poisoning. He also produced an increased red cell count averaging 6,700,000 in six guinea-pigs by exposing them one hour a day for seven days to one part per 1000 CO. The blood saturation with CO was 25 to 30 per cent.

There is a relapsing form of carbon monoxid poisoning which has been often described and in which, after apparent recovery and a period of fair health, serious symptoms develop that may lead to death or insanity. Poelchen's (9) case was a striking instance of this. A woman, severely poisoned with carbon monoxid, lay unconscious for two days, recovered except for a slight impairment of speech, carried on her housework for eighteen days, but, 26 days after the accident, suffered a relapse. There was increasing difficulty in all her movements, almost complete loss of speech, increasing rigidity of the limbs especially on the right side, and mental apathy. Then suddenly the rigidity ceased and she fell into a state of somnolence, with paralysis of the bladder and intestines, and died without recovering consciousness. Poelchen remarked that in East Prussia the opinion was general that those who survived CO gassing

* The figures have been changed to parts per 1000, in order to make them uniform with the others in this chapter.

sooner or later became mentally affected. Several instances of this relapsing form are described by McConnell and Spiller (33) of Philadelphia.

Lewin, who has had much to do with the medico-legal aspect of industrial poisoning in Germany, says that these cases present great difficulty when it comes to deciding questions of compensation. He mentions a man who after severe gassing recovered and at the end of 36 hours was apparently well except for headache, but 20 days later he had a recurrence with increasing paralysis of the limbs, which was complete on the 24th day, and on the 25th he died. Another victim of gas was able to be up and about for five or six days after his accident, then he was seized with convulsions, followed by lockjaw and death. After slighter poisoning, Lewin has often seen pneumonia come on some six to 14 days later; after serious poisoning there may be mild or severe nervous symptoms, sometimes no more than what is usually classed as an "accident neurosis," that is, a sense of weariness and general illness, with pains in the legs, but sometimes much severer symptoms, such as blindness, deafness, paralyzes of various kinds, or delirium or dementia. This latter class of cases may also develop pneumonia and bloody urine. The prognosis is always poor in cases that suffer a relapse.

Carbon monoxid can pass from the mother's blood into the blood of the fetus and according to Nicloux (34) the latter may contain an equal quantity of the gas. Lewin describes the case of a woman who toward the end of her pregnancy attempted suicide with illuminating gas. She was found unconscious and eleven hours later gave birth to a dead child which was, however, so rosy that the midwife attempted artificial respiration, unable to believe that it was dead. It was found that one-fifth of the baby's hemoglobin had taken up carbon monoxid. In another case the mother's blood contained 18 per cent carbon monoxid and the blood of the fetus only 4.07 per cent. It has long been believed, since Roman days in fact, that the smoke from extinguished candles would bring about premature labor, and Lewin believes that there is evidence to show that an amount of carbon monoxid in the blood of the mother which is too slight to produce symptoms in her striking enough to arouse attention, may be quite enough to kill the child in utero, and that such poisoning is probably fairly common in industries where women are employed and where the air is vitiated with carbon monoxid. He tells also of an instance of abortion from CO poisoning. A pregnant woman was working on a printing press which was driven by a gas motor. Some accident allowed gas to escape, the woman was seized with symptoms of carbon monoxid poisoning, and aborted.

There is a great difference in individual susceptibility to carbon monoxid, as is seen in every accident involving a large number of persons. For instance, in the greatest mine disaster on record,

in the Courrières district in France, 1,100 men died from carbon monoxid, but 13 survived. It has been said by some that women are less susceptible than men and that in cases of family poisoning it is more likely to be the woman who escapes with her life than the man, but it has also been pointed out that in such cases the source of the gas is usually some leak from the domestic supply and it is possible that the woman, employed in the house for most of the time, has acquired a partial immunity by breathing small quantities of gas for many days. Oliver (20) thinks there is some evidence of an acquired immunity in workmen continually exposed to gas. He quotes Englis who has seen lads in the iron works of the Tyne grow to men in the industry. These boys complain of lassitude and weariness, insomnia and loss of appetite, and if they join in games they suffer from palpitation and breathlessness. But as they grow to manhood these troubles seem to pass away and they seem to have acquired immunity. According to Glaister, experienced foremen in industrial establishments in England believe that vigorous young men are especially likely to be gassed, and that middle aged men should be selected for a piece of work which involves exposure. Glaister explains this on the ground of the deeper respirations in the young. Old men also are likely to suffer damage from the gas more than the middle aged because of degeneration of the blood vessels.

Chronic Carbon Monoxid Poisoning.—The question whether prolonged exposure to small quantities of CO produces chronic poisoning is still in dispute. Recently K. B. Lehmann in answer to an inquiry from the International Labor Bureau said that he believed there is such a thing as chronic carbon monoxid poisoning. Lewin discusses it at length and says it cannot be regarded as an accumulation of the gas in the body which, when it reaches a certain degree, brings about characteristic symptoms; for this to happen a person would have to remain continuously in air containing CO, but this is never true in actual life, the CO acquired in contaminated air is always sooner or later discharged in pure air. Therefore, carbon monoxid cannot act like a cumulative poison, but although a chemical accumulation cannot take place, a functional can. That is, there may be a cumulative effect of all the injuries done to the blood and indirectly to the tissues. This injury may be simply a disturbance of nutrition from anoxemia, but as a result, toxic products may be formed and these produce their own effects. Lewin does not, however, believe that the vascular changes of acute CO poisoning have anything to do with the symptoms of chronic poisoning.

The changes in the blood have been studied in connection with chronic exposure to carbon monoxid with varying results. Some observers find that the effect of saturating part of the red corpuscles with CO is to cause an increased production of red cells. Von

Jaksch reports a blood count of 6,390,000. Glaister found counts of 8,200,000 up to 11,200,000 in a stoker in a gas works who was suffering severely from loss of muscular power, loss of appetite, and pain in head and abdomen. Apfelbach and Karasek examined the blood of steel workers in the course of the Illinois Occupational Disease Survey in 1910 (30). Sixty-eight men, all of whom had either been recently gassed or subject to frequent mild attacks of gassing, were selected and the blood examined for hemoglobin and red and white cell counts. They found an increased red cell count running from 5,500,000 to 9,676,000, more than half, or 66 per cent, being over 6,000,000 but no immature red cells were found. The hemoglobin ran from 95 to 125 per cent, a larger number being over than under 100 per cent. Some years later, in 1917, the Illinois Steel Company undertook an examination of 176 blast-furnace and open-hearth men at the Gary and South Chicago plants. (See Forbes (35).) They found only 15 per cent with red counts over 5,600,000, and only 2.2 per cent over 6,000,000. In this examination also the white cell count showed nothing of interest.

An increase in red cells has been produced in animals without any symptoms of ill health. Nasmith and Graham (36) succeeded in keeping the blood of guinea-pigs saturated with carbon monoxid up to 20 per cent for days at a time. The animals were lively and continued to gain weight normally, and their blood showed a decided increase of red blood corpuscles. It must be remembered, however, in dealing with such results as these in workmen that a group of men who have worked for years at blast furnaces and open hearths, many of them working twelve-hour shifts seven days in the week, cannot be regarded as average men. They are a selected group, for men of average physique cannot endure the strain. An accurate picture of the effect of continual exposure to carbon monoxid, not an occasional gassing, could only be obtained by examining not only the men still employed but those who have been obliged to drop out.

An interesting finding and one which, if confirmed, would be of decided economic importance, was that made by Karasek and Apfelbach in the course of the investigation already referred to. They examined 400 workers, half of them employed in the steel works of South Chicago, the other group employed in plants where there was no possibility of carbon monoxid poisoning. The two groups were of the same nationalities and the character of their work was similar, as were also their home conditions. A comparison was made of the muscular strength of the hand, using the ordinary hand dynamometer, and, as shown below, it appeared that the steel workers exposed to carbon monoxid had decidedly less muscular strength than workmen of the same age not so exposed.

Ages 20 to 40:	Average strength
Steel workers	117.13
Car-company workers	146.11
Other trades	134.43
Ages over 40:	
Steel workers	94.3
Car-company workers	127.25
Other trades	113.01

Carbon Monoxid in Industry.—Blast-furnace gas is very rich in carbon monoxid, resulting from reduction of the oxid ores by means of glowing coke, and in addition there is the carbon monoxid formed by the burning of the coke. German blast-furnace gas contains from 24 to 25.97 per cent. American analyses usually demonstrate about 26 per cent, though sometimes as high as 30 per cent. Power, producer, and generator gas contain different amounts of carbon monoxid, according to the source and method of production, the limit being from about 22.8 to 26 per cent. The smoke from locomotives contains little CO according to analyses made in this country. For instance, in the tunnel of the Baltimore and Ohio railroad under the city of Baltimore only 25 parts of CO per million parts of air were found.

Illuminating gas varies in composition in different cities, the proportion of CO depending on the amount of water gas which is added to the coal gas. European cities use coal gas to a much greater extent than is used in America, and therefore the gas in such cities as London, Paris, Berlin, contains only from about 4 per cent CO to $7\frac{1}{2}$ per cent, and accidental poisoning from leaking gas pipes is not nearly so deadly as in this country. According to McNally (37) the following is a typical analysis of gas from a city main in Chicago:

	Per cent
Carbon monoxid	26.9
Carbon dioxid	5.0
Illuminants	8.4
Oxygen	2.7
Hydrogen	31.2
Methane	11.2
Nitrogen	14.6

Analyses from other cities sometimes show a carbon monoxid content as high as 31.5 or 32 per cent.

The exhaust gas from the engines of motor cars contains a varying proportion of CO. Schumacher, city chemist of Chicago, found 9.3 per cent. Henderson and his colleagues have found 5.6 per cent, 6.4 per cent, 6.6 per cent, etc.

The fatalities from carbon monoxid poisoning in British indus-

tries have increased since 1914 from 12.3 per cent of all cases of gassing to 17.3 per cent. We have no accurate statistics in this country and only general statements can be made as to the frequency of gassing and the proportion of fatalities in steel works, in the use of industrial gases, and in the mining of metal and coal.

Steel.—The modern blast-furnace gives off 150,000 to 200,000 cubic feet of gas per ton of fuel consumed. The charging is now done automatically and the gas is no longer allowed to escape into the air but is utilized for fuel, having about one-half the heating value of coke. These gases pass through “downcomers” and mains to be freed of dust and then on into scrubbers and washers where a stream of water removes various by-products such as benzene. Since the purpose of the blast furnace is to bring about reduction of iron ores by means of the carbon monoxid which is formed by the burning of coke or coal there is sometimes a very high proportion of this gas in the blast furnace. When the heat in the furnace is between 600° and 700° C., combustion with air results in the formation of carbon dioxid chiefly, but from that point up to $1,000^{\circ}$ C. carbon monoxid is produced in increasingly large proportions and above this point practically all the carbon is given off in this form. As the zone of fusion is at a temperature of $1,200^{\circ}$ to $1,600^{\circ}$ C. it is easy to understand how great is the risk of gassing at the top of the furnace and how much more dangerous is the old type of top-filler furnace, some of which are still in use in the larger plants and many in the smaller.

Some of the most serious cases of gassing occur in cleaning out the dust from the flues, which is usually done twice a year. The flues are flooded with water first, to cool them and lay the dust, but a five-foot flue may be almost full of very fine dust, and the water soaks in only part way, leaving underneath, dry dust, with sometimes pockets of gas; then, in digging, the man opens these pockets, and sometimes receives a fatal dose of CO. Other very dangerous jobs are those of the second and third helpers on the open hearths, and the men who clean the furnaces.

The Illinois Steel Company, which has three large plants near Chicago, has records of the cases of gassing which have occurred during two periods: The first was from 1912 to 1915, inclusive. Among 1,112 men employed at the blast furnaces and in the boiler house, the average number of cases of CO gassing per year, that is, of cases severe enough to require medical care, was 66, and the average number of deaths per year 3.25, making a mortality of only 5 per cent, which is decidedly lower than the British rate of 22.8 per cent for the period 1914 to 1919. Even better is the record for the five years 1916 to 1920, during which time there were 271 cases, with 13 deaths, representing a mortality of 4.8 per cent.

Nevertheless, extensive and disastrous accidents do still occur from the escape of carbon monoxid gas, every now and then, in American steel plants. The wholesale poisoning of some 55 men during the fall of 1919, in a plant of Pennsylvania, illustrates very strikingly the sudden deadly effects of this gas, and the lack of warning, because of the absence of irritating qualities. For the details of this incident, I am indebted to Dr. Francis D. Patterson, at that time Medical Commissioner of the Pennsylvania Department of Labor and Industry.

The men were engaged in relining a blast furnace, which for twenty-two days had been cut off from the gas mains while the repairs were in progress, but water seals were used to prevent the gas which was passing through the mains from reaching this particular furnace. The company had been warned that this procedure was dangerous and had been instructed to use goggle valves, but had neglected to do so. They placed a watchman at the seal, to see that water kept running from the overflow pipe, but he was ignorant and when the water ceased to flow he gave no warning to the men in the furnace but went to the pump house to report. The gas forced its way through the lowered water seal carrying 10 or 15 per cent CO and 55 men were overcome, of whom 25 died.

In 1916 the United States Bureau of Mines made a study of the danger spots in the steel industry, so far as gassing accidents were concerned. Their report describes some 120 cases of asphyxiation, usually fatal, either from the direct effect of the gas itself or from an accident which occurred because of the loss of consciousness brought on by the gas. The sources of the gas in these accidents are the following:

Bustle pipes	6	Gas outside of boilers.....	16
Furnace stacks	1	Downcomers	3
Blast-furnace tops	17	Mains	34
Hot-blast furnaces	4	Holders and washers.....	12
Cleaning boilers	4	Miscellaneous	23

Some of the more interesting instances have been selected from the report. A man was overcome with gas on the bustle-pipe platform and was drowned by falling into a water trough. An electrician was asphyxiated while changing carbons on an arc light on the sheave-wheel platform. Two men on the top of the boiler were enveloped in a cloud of steam, and becoming bewildered, they tried to escape the steam by going to the front of the boiler, but there were no steps down from that side, and by the time other men had succeeded in closing off the steam and had come to look for them, one of them had been fatally gassed from the leaky burners beneath. Twelve men were overcome by gas, and two of them died, in attempting to close an explosion door beneath a boiler-house roof blown

open by a slip. The largest number from any one department in this list came from work in the gas mains.

Mining.—The gaseous impurities in the air of coal mines and metal mines come from the use of explosives in blasting; from mine fires, due not only to the burning of wood used in construction, but also the burning of pyrite ores, or native sulphur; from accidental explosions of coal dust; and from the gases given off by shale.

Since blasting is a normal process of mining, the gases formed by different explosives are more important than those formed by any accidental occurrence. Tests made by the Bureau of Mines show that the detonation of explosives produces large quantities of carbon monoxid, the burning of explosives a smaller quantity. German experiments have shown that the explosion of celluloid forms a gas containing 45.7 per cent carbon monoxid, while the burning of celluloid films has been known to give off gas containing 26.3 per cent. The explosion of gunpowder results in a gas containing only 3.6 to 9.26 per cent carbon monoxid, but the gas from the explosion of pyroxylin contains 46.98 per cent; of dynamite 34 per cent; of trinitrotoluene 57 per cent; and of picric acid (lyddite, mélinite), 61 per cent (38). The gases that are found in mines and tunnels after explosions produce their effect chiefly through their carbon monoxid content, although if there is much hydrogen sulphid present this may also have a toxic action.

Next to blasting the commonest source of CO and other gases in mines is the burning of coal dust, or of timbers, or the slow combustion of the coal itself, the gas seeping into the working part of the mine because it has been incompletely walled off. Slow-burning fires, without explosion, are not uncommon in the coal mines of Illinois, Iowa, and Missouri. The burning areas are often shut off and ignored, and then CO may find its way through leaks. In fighting mine fires, carbon monoxid is the great danger. The spontaneous explosion of coal dust results in the formation of carbon monoxid in dangerous quantities. Another source of this gas is the internal combustion engine, such as is used for gasoline driven pumps and locomotives, for the exhaust gas contains usually about 6 per cent CO, sometimes as much as 13.5 per cent.

The danger from mine gas is increasing in the United States, as the mines grow deeper, for the deeper the mine, the more the gas accumulates, the greater the difficulty of maintaining adequate ventilation, and the greater the possibility of men being trapped in inaccessible places. It is not possible to discover from the statistics published by the Bureau of Mines, how many of the fatalities in mining have been due to the effect of gas. Apparently suffocation from mine gases caused 263 out of the 52,187 deaths between 1870 and 1914; and suffocation by powder gas, 127 cases; but there are several other headings under which it is reasonable to suppose deaths

from gas are included, although they cannot be separated from the deaths from burning and from the violence of explosion.

Hayhurst (39) made a thorough study of the health of coal miners in Illinois and Ohio. He states that there is not so much carbon monoxid in these mines as in Montana copper mines, because blasting is not continuous, the shooting being done at the end of the shift. He was not able to discover any serious after-effects of acute poisoning, nor any evidence of chronic CO poisoning.

According to Forbes (35) carbon monoxid gas in Montana copper mines collects frequently in small amounts about the fire areas and is rather troublesome, and the same thing is true of the gas after blasting at points where the air current is not good and where two or three shifts are working. In the coal mines, especially in the south, there is usually free ventilation because of the danger of explosions from natural gas and fine coal dust, but the iron ore mines of Alabama are less well ventilated and after blasting the CO lies in the fine dust and is stirred up by the muckers, who often have headaches from it. Yet in neither of these areas is there apparently any record of lost time due to the gas.

It is easy to obtain histories of acute gassing in any steel town or coal mining town, but it is a very different matter when one tries to discover how much lasting damage is done by even the severest forms of gassing which are not fatal. Apparently the man either dies or recovers completely. Careful inquiries made in the steel towns of the Chicago district and of the Pittsburgh district, and in South Bethlehem, yielded absolutely no evidence of serious after-effects (40). I talked to physicians in these cities who are quite familiar with all the manifestations of severe acute gassing, but none of them had seen any of the remoter effects, such as pneumonia, or cardiac weakness, or loss of memory, or paralysis. Nor was I able to gather any such information by interviews with the furnace men themselves, or the clergymen, or charity workers. That this was not due to a desire to conceal facts, was evidenced by the frankly pro-labor attitude of several clergymen, who freely denounced the policy of the companies with regard to the twelve-hour day, the seven-day week, and the personal relations between employers and men, so that the fact that they knew of no permanent damage following a gassing accident seemed to me very significant. Certainly a case of paralysis or mental deterioration would become a matter of ordinary knowledge in such a community. I succeeded in obtaining the history of the 30 men who survived the water-seal accident related above. Eighteen months later they were still in the employ of the same company and none showed any effect from the gassing which could be determined by ordinary medical examination.

My experience receives confirmation in a paper by H. S. Forbes (35), who made a much more extensive study of carbon monoxid

poisoning in mines and mills. He visited metal mines, coal mines, blast furnaces, and producer gas boilers, and engine rooms in Montana, Colorado, Oklahoma, Arkansas, Alabama, Tennessee, Kentucky, and Pennsylvania, and although he found that acute gassing was fairly common, he could rarely find evidence of late after-effects following such an accident except when there was a pre-existing pathological condition. Nor did he find that frequent exposure to carbon monoxid, as is experienced, for instance, by the top fillers on blast furnaces and pipe fitters and repair men, was followed by a cumulative harmful effect.

Forbes believes that there is evidence of a certain degree of tolerance acquired by men exposed frequently to gas, and he gives an instance, a mine foreman of fifty years who had done mine work since he was a boy and who for months at a time had had daily headaches yet was sure that he could stand more gas than he could at the beginning and more than a green hand could stand. On the other hand he also met miners who thought that a series of severe gassings had left them with impaired health.

These results are not at all in harmony with the experience of Europeans in this field. Glaister calls a dulled mentality with loss of memory the characteristic sequela of a colliery accident. The slow absorption of the gas and the long period of exposure which is so often true of mine gassing should, one would suppose, be followed by the changes in brain and cord which are observed after poisoning by illuminating gas or in garages. There is no satisfactory explanation for the absence of such after-effects in American coal miners and I can only hazard the suggestion that the reason why our experience is different from the British lies in the fact that we are dealing with non-English speaking foreigners while the British physicians deal with men of their own nation and language. It is excessively difficult to get information concerning possible psychical symptoms in a miner who speaks English imperfectly or not at all, who has no family or intimates in the place, and who passes muster as entirely normal provided he can carry on his day's work as well as he did before the accident. A lawyer with many years' experience under the Illinois compensation law told me of the difficulty he had in determining injury of this kind in Slavic miners whose English was restricted to a few words necessary for the performance of their day's work. Even when he could convince himself that the victim of an accident was in a condition of mental dullness, was slow to respond, was easily confused and upset, and was unable to make a decision promptly, he could not get enough evidence as to the man's mentality before the accident to make it possible for him to prove that his condition was of recent origin. This may really be the explanation of the failure to discover in the coal and metal mining districts visited the sort of injury following gassing accidents

which the British find common enough to call "characteristic of colliery accidents."

Illuminating Gas.—The manufacture of illuminating gas is seldom attended with accidental gassing. Fatal accidents are almost unknown. The employees of gas companies who suffer most from gassing are the testers of meters and the men doing extension work, that is, making connections for new lines and working in ditches and trenches and manholes. In one city an official of the gas company told me that they expected the men in extension work to get gassed, but that the only thing to do was to have someone watch at the top of the ditch, and when the man staggered and fell, pull him out and send another in.

The American Gas Institute has a committee on accident prevention and this committee has reported some 11,000 accidents in the industry between 1915 and 1919. There were 30 deaths, only 4 of which were caused by gas. The records for 1919 cover about 1,000 accidents occurring in 77 plants. Thirty of these were men overcome with gas, but none of them died. The opinion held by this committee is that practically all cases of gassing recover within 48 hours, with no permanent effects.

An increasingly important source of CO poisoning is garage work, especially repairing, for the engines running idle poison the air unless a hose is attached to the exhaust to carry the gas off. In 1918, L. I. Harris of the New York City Department of Health investigated 43 garages in that city. He states that many cases of more or less severe gassing had been reported to the Department during the winter and he ascribes the excess of CO in the air of these places partly to the lack of heat. The engines become cold and it is difficult to start the motor so that engines are often kept running for many minutes. The testing of engines for repairs adds greatly to this evil. Tests made in small garages by the U. S. Bureau of Mines in 1919 indicated a concentration of CO as high as 19.8 per 1,000 parts of air after the engine had run 10 minutes, and 32 per 1,000 after 35 minutes. It must be remembered that an engine running idle produces more CO than when under a load.

The New York State Department of Labor (in Special Bulletin 101, Dec., 1920) reports the inspection of 1,308 garages and auto repair shops in that state. One hundred and thirteen cases of asphyxiation (degree not stated) were found to have occurred within two years, all but 12 of them outside New York City. Only 36 of the 1,308 shops had the proper type of ventilation, by tube attached to the exhaust pipe and leading directly out of doors.

I made an effort during the winter months of 1921 to see whether the blood of garage workers would show the presence of CO by the tannin precipitation test (40). The temperature during that time was low enough to cause garages to be kept closed as much as possible.

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The effect of exhaust gas was well known to all these men and many admitted suffering from headache, weakness in the legs, sometimes constipation, less often nausea, dizziness and vomiting. Of 55 mechanics and storage men, 36 gave a positive test for CO, and of the other 19 only 9 had been at work inside for more than an hour when the test was made.

Aside from garage men there are many industrial workers who are exposed to small quantities of CO in the course of their work, such as:

- Laundry workers, especially ironers.

- Pressers in tailor shops.

- Furnace tenders.

- Gas workers, especially men making connections and reading meters.

- Painters working in rooms in which salamanders are kept burning to dry the walls.

- Printers, especially linotypists, and men working at type melting kettles heated with gas.

- Molders of metal where gas is used for heat.

- Workers in canneries on soldering machines.

- Miners, especially in mines where blasting is done continuously.

A tannin precipitation test applied to the blood of 47 linotypists working in Boston newspaper shops in the winter of 1921 showed that 8 had absorbed a demonstrable amount of carbon monoxid.

Unusual sources of accidental CO poisoning in industry are so numerous that it would be impossible to enumerate them and I have selected only a few of the more important.

Albaugh (41), while director of the division of industrial hygiene of the Ohio State Department of Health, relates a very unusual occurrence in a construction camp. Sixty men were living in a bunk house constructed on an old dump where dirt, slag, scrap, mill waste, ashes, and cinders had been deposited for a period of about five years. In December, 1916, during a week's time, 14 men were severely gassed and three died. After it had been shown that these were not cases of food poisoning, but that some gas was present in the air of the bunk house, affecting even the physicians and rescuers, a search was made for the source of the gas. It was found that about 10 days before a little steam was seen to be rising from the edge of the dump about 50 feet from the bunk house, although no ashes or cinders had been deposited there for the last six months. Digging into the heap they found it was frozen on top, but at a depth of five feet the cinders were red hot. Evidently carbon monoxid, formed by the incomplete combustion of the cinders, had seeped up through the soil which under the bunk house was melted, and had passed through the plank flooring to the sleeping rooms. I was told by Apfelbach of two men who died from CO inhaled while they were

raking hot cinders out of doors, and I found the history of a similar case, also fatal, in the Perth Amboy City Hospital.

Harris tells of an accidental poisoning, fortunately mild in character, in three lofts in New York City. Gas from the chimneys blew down through the skylight to the rear hallway and entered the rear end of the three lofts, affecting 73 clothing makers who were working at that end of the building.

Albaugh investigated the poisoning of several inmates of an Ohio state institution who were sent into a silo to empty it and were overcome by a gas which proved to be CO. A similar case was reported recently by British factory inspectors. A brewery employee undertook to clean a vat on Sunday when the place was empty, and the next day when the men came to work he was found dead in the vat.

Another unusual source of CO is reported from a German smelter. (42) The gas was evolved from the charcoal and organic constituents of specular iron during casting, and affected three young apprentices and one workman. One of the lads, feeling ill, climbed up on a disused furnace where he was found dead the next day. The explanation lay in the fact that the metal contained 40 per cent of specular iron and this when molten gives off 19.1 per cent CO as against 4.5 per cent given off by other iron.

In connection with all forms of gassing which are not caused by pure CO, it is important to bear in mind the other toxic gases which may possibly be present. Thus in the making of coke the by-products are tar, naphthalene, benzene and toluene; the gases given off are carbon monoxid, carbon dioxid, cyanogen, hydrogen sulphid, sulphur dioxid, and marsh gas or methane. This is according to the statement of the superintendent of a large plant near Pittsburgh. The great danger here is benzene, and carbon monoxid is relatively negligible. When celluloid burns with or without explosion a large quantity of CO is given off, with some HCN and NO, nitrogen oxid. Lodemann (43) analyzed the gases produced by burning nitrocellulose films and found that one gramme under ordinary heat and pressure produces 600 c.c. of gas, of which CO makes up 260 c.c., nitrogen oxid 150 c.c., and HCN 5 c.c. Such decomposition may take place without any flame and the production of the gases be quite unsuspected.

The large proportion of hydrocarbon illuminants in water gas is also of great significance. One of the city gas companies which answered my inquiry as to this point stated that in manufacturing illuminating gas, 2 gallons of light oil were added to 10,000 cubic feet of gas, and that this oil consisted of three parts benzene and one part toluene. The resulting gas was said to contain benzene in the proportion of five parts per thousand parts of gas. In another city the coal gas used contains from 0.5 per cent to 1.0 per cent of ben-

zene, one-third as much toluene, and one-fifth as much xylene. This coal gas is mixed with water gas in varying proportions, but usually sufficient to bring its carbon monoxid content up to 27 to 29 per cent, probably about one part of coal gas to two or two and a half of water gas, which would dilute the benzene decidedly, for water gas does not contain benzene. Still, even one-third or one-fourth of the above quantity of benzene is probably enough to constitute a menace.*

The difference between pure CO and CO mixed with coal tar distillates has been shown in repeated experiments. Thus Stachelin (44) was experimenting on frogs with pure CO and when his supply ran out he thought to substitute coal gas but his frogs showed excitatory symptoms which had not appeared under CO. He then tested the effect of benzene and found that these same symptoms, excitation followed by rigor of muscles, could be brought on by the amount of benzene which was present in the coal gas.

The experiments of Henderson and his colleagues with exhaust gas from engines running with coal distillate fuel, described in the chapter on benzene, show that the gas from this motor fuel contains not only CO but an additional toxic body and it is very striking to see in Haggard's studies on the growth of the neuroblast in the presence of CO that while this gas had no injurious effect on the cells, even in a concentration of 79 per cent, illuminating gas was quickly toxic in a concentration of 0.1 per cent.

Even in steel works the gas which is formed may contain other toxic elements besides CO. A recent report from Germany is interesting in this connection. In a plant situated in the Saar valley, dry scrubbing of the furnace gases had been substituted for wet. The report, which is made by a factory inspector, states that after this change was made several men were overcome by gas from the scrubbers, but although the acute symptoms were quite like those of ordinary carbon monoxid gassing, the men did not recover completely but were left with a very decided mental impairment which necessitated commitment to the insane asylum. The report was made some three months after the accident and during that time there had been no improvement in their condition. Nothing of the sort had ever been observed at the plant while the wet scrubbing was used, showing that some compound or compounds which were formerly removed by the wet process remained after the dry scrubbing. The management suggested that possibly some arsenical or cyanogen compound might be responsible.

* One of the large city gas companies gave me an analysis of the gas manufactured during March, 1920. The toxic constituents were: Carbon monoxid 31.61 per cent; acetylene 4.62 per cent; benzene 0.51 per cent; toluene and "higher aromatics" 0.35 per cent. No trace was found of arsin, phosphin, hydrogen sulphid, hydrogen cyanid or cyanogen.

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MINE GASES

Most of the gases encountered in mines have already been treated under separate headings (carbon monoxid, hydrogen sulphid, and the oxids of nitrogen), but it is well to add a few words descriptive of the so-called "fire damp" and "black damp." The former is marsh gas, CH_4 , and it is not toxic but very inflammable, even explosive, when it is present in the air in any quantity above two parts per 1,000. A cap of luminous flame appears over the miner's lamp and gives timely warning of danger, for air containing from 50 to 130 per 1,000 is explosive. The only effect it has on the body is an indirect one, by diminishing the oxygen of the air to too low a point, but it is very light and therefore if a man faints from lack of oxygen and falls to the ground he falls into purer air. (Haldane (1).)

Black damp is a residual gas, a mixture of nitrogen and carbon dioxid, which is produced usually from the action of air on oxidizable material in coal such as sulphid of iron. Miners test for this gas by lowering a candle into the shaft and if the flame goes out it means that there is less than 17 per cent of oxygen in the air, for a candle will not burn with less than this amount of oxygen. Haldane says that black damp consists of 13 per cent carbon dioxid and 87 per cent nitrogen. The symptoms caused by breathing it are partly due to lack of oxygen, partly to CO_2 , and they appear when the oxygen has fallen to 12 per cent. If the proportion of oxygen falls to 8 per cent there is intense headache, especially on stooping, breathing is deep and rapid, and at 5 or 6 per cent there is clouding of

the senses followed by loss of consciousness; but if the miner is obliged to make great exertions death may come on when there is still 8 per cent of oxygen in the air. Death from black damp in mine accidents usually occurs when the oxygen is down to 5 per cent, and the cause is to be found rather in the lack of oxygen than in the presence of carbon dioxid. There is more abdominal pain and diarrhea from black damp than from carbon monoxid. (2)

A very singular case of poisoning, supposedly from carbon dioxid, was reported recently by factory inspectors in Holland. A man was sent to clean a linseed oil reservoir which had been emptied of oil 14 days before, but a layer of oily water was left behind. He was let down into the reservoir by a rope around his waist, untied the rope, and then collapsed suddenly and fell headlong into the water. A second man was lowered, but before he could make any attempt at rescue he too fainted away. He was drawn out and came to himself promptly in the fresh air, but the first man died before he could be lifted out. It was supposed that a yeasty fermentation had taken place in the linseed oil residue at the bottom of the reservoir, and as a result carbon dioxid had formed and lay in a thick layer just over the surface of the oily water. An old workman remembered that many years before a similar accident caused the death of two men.

In another linseed oil works also in Holland, a similar accident was reported. Here also a man was let down into a reservoir containing crude linseed oil and water. He too untied the rope around his waist, then fainted and fell into the mixture of oil and water where he was drowned.

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CHAPTER 28

PETROLEUM DISTILLATES

PETROLEUM

THE petroleum or aliphatic or fatty series, contains a large number of compounds which are important in industry. The petroleum distillates are mixtures of hydrocarbons from CH_4 to $\text{C}_{35}\text{H}_{72}$, having their boiling point between 30°C . and over 300°C . The derivatives which are industrially important belong to the alcohols, ethers, aldehydes and ketones, halogen compounds, and a few salts of acids. They may be grouped as follows:

Alcohols: methyl or wood, CH_3OH ; ethyl or grain, $\text{C}_2\text{H}_5\text{OH}$; and amyl or fusel oil, $\text{C}_2\text{H}_{11}\text{OH}$.

Ethers: Diethyl or sulphuric ether, made by the action of H_2SO_4 on grain alcohol. $(\text{C}_2\text{H}_5)_2\text{O}$.

Aldehydes and Ketones: formaldehyde, CHOH ; dimethyl ketone or acetone, $\text{CH}_3\text{COCCH}_3$; methyl-ethyl ketone, $\text{CH}_3\text{COC}_2\text{H}_5$; acrylic aldehyde or acrolein, CH_2CHCHO .

Acids and Salts: acetic, CH_3COOH ; amyl acetate or banana oil, $\text{CH}_3\text{COOC}_5\text{H}_{11}$; methyl acetate, $\text{CH}_3\text{COOCH}_3$; dimethyl sulphate, $(\text{CH}_3)_2\text{SO}_4$; methyl-p-amino-phenol-sulphate or metol; monochloroacetic acid, CH_2COOHCl .

Halogens: methyl chlorid or monochloromethane, CH_3Cl ; carbon tetrachlorid or tetrachloromethane, CCl_4 ; acetylene tetrachlorid or tetrachlorethane, $\text{C}_2\text{H}_2\text{Cl}_4$; dichlorethylene, $\text{C}_2\text{H}_2\text{Cl}_2$; trichlorethylene, C_2HCl_3 ; methyl bromid or monobromomethane, CH_3Br .

Nitric esters: ethyl nitrite, $\text{C}_2\text{H}_5\text{ONO}_2$; glyceryl trinitrate or nitroglycerin, $\text{CH}_2\text{-O-NO}_2$ CH-O-NO_2 $\text{CH}_2\text{-O-NO}_2$.

It is important to distinguish clearly between the petroleum solvents and the more highly toxic coal-tar solvents, benzene and toluene. It is very unfortunate that there should be two words so similar as benzin and benzene covering such different compounds and that the term "solvent naphtha" should mean not petroleum naphtha but a mixture of coal-tar distillates. (See page 456.) The confusion is increased by the fact that both classes of solvents are used in the same industries, and in the foreign literature it is sometimes impossible to tell just which body is meant by the writer, whether coal-tar benzene or petroleum benzin.

Up to 1914 the coal-tar solvents were not used to a great extent in

American industry, they were imported from Germany and were much more expensive than the petroleum distillates. Then, when the war shut off the German supply it also caused at the same time an enormously increased demand. Rubber manufacturers had begun to use anilin (amido-benzene) as an accelerator for the production of which they needed benzene and it was also needed for the new dye works and for the production of explosives. Picric acid for the French and trinitrotoluene for the British and Russians necessitated the use of great quantities of benzene and toluene, and therefore coke by-products plants were erected to collect these light distillates which had formerly gone to waste, and the illuminating gas works began to remove toluene from the gas. The end of the war found us with large quantities of coal-tar distillates for which new markets had to be found, and consequently these solvents have found their way into a great variety of industries, displacing the petroleum distillates more or less. The latter solvents, however, are still extensively used.

Acute Naphtha Poisoning.—The volatile petroleum oils,—naphtha, benzin, petroleum ether—have a toxic action on the central nervous system. A number of human experiments were made by Felix (1) on prisoners in the penitentiary of Bucharest. He administered benzin as chloroform is given for anesthesia, measuring the quantity accurately, and found that in most subjects 5 to 15 grams given over 7 to 12 minutes would cause dizziness, nausea, vomiting, drowsiness, injection of the conjunctiva, and burning sensation in the chest. Anesthesia and sleep followed the administration for 8 to 12 minutes of 20 to 40 grams, but some individuals showed themselves very resistant to the effects, others unusually susceptible.

Haggard (2) tested gasoline vapors on dogs and found that in the first experiment symptoms began at 85 parts in 10,000, and when 156 parts were reached, the animal was unable to stand. Taken out, the dog developed clonic spasms but made a fair recovery in half an hour, was depressed and without appetite the next day, but quite well on the third day. A second dog had muscular spasms when breathing 102 parts per 10,000 of air, and epileptiform convulsions came on when the amount was 162 per 10,000. At a dilution of 192 parts per 10,000 the dog was still, but when removed from the chamber convulsions recurred lasting 12 minutes. The third dog went into convulsions in an atmosphere of 160 parts per 10,000, was unconscious at 238, and died in two minutes when 243 parts were present in the air.

Acute poisoning in industry is characterized by symptoms of mild intoxication of the central nervous system. There is an increasing restlessness and excitement very like that of alcoholic intoxication, to some men it is pleasurable and they become hilarious, others are

irritable and unreasonable and prone to quarrel. A foreman in a rubber spreading department told me that he always had to be careful how he spoke to his men toward the end of the day. Girls sometimes become slightly hysterical with uncontrollable laughter and silly behavior (Dufour (3)). This condition is known as a "naphtha jag" and is familiar to workers in rubber factories. There may be also an inclination to cough, a feeling of irritation and constriction in the throat, trembling of hands and arms so that fine work is very difficult, and there may be a sensation of crawling over the skin. Painters working with quick-drying paints in interior decoration sometimes complain of spots before the eyes or even of cloudiness of vision, and a girdle-like sensation around the waist (4).

As with Haggard's dogs the symptoms may be felt with greater intensity after the man has left work and has gone out into the open air. In a ship-building yard I was told of a man who was painting a water bottom with hot, fuming asphaltum paint. He had a headache and was dizzy while he was at work, but when he came out into the open air he suddenly became violently delirious. The stage of excitement of a naphtha jag passes into a heavy stupid feeling with a sick headache, a restless night, and a wretched morning, with nausea and general misery.

The more serious forms of poisoning occur usually when men are obliged to go into a tank or a tank car which has held petroleum, as apparently must be done now and then in the refineries or oil wells. The workman is likely to be seized suddenly with drunken excitement, to shout and sing, refuse to leave the tank and have to be forced out, sometimes at the expense of the life of his rescuer (5). Then consciousness is lost, the skin is cyanosed, the eyes are staring, and there is foam on the lips. The pulse is first rapid, then slow, and there is a fall in respirations and temperature. Such poisoning ending in death has been reported from refineries, from oil wells, and from work in gasoline tanks and tank cars.

German factory inspection reports tell of the death of a man using benzin to clean a distillery vat, another of a man who fell asleep near a leaking benzin tank, and of three men who died from benzin fumes in a carpet cleaning establishment. Plummer (6) published the history of a 16-year-old lad, an apprentice to an English firm of electrical engineers, who was sent to clean out a pit in a private garage, the car being outside. About three or four minutes later he was seen to be crouching in a corner of the pit, evidently dazed. Lifted out and carried to the fresh air he vomited violently and was out of his head, then lapsed into unconsciousness and Plummer found him in this state, with shallow respirations, weak thready pulse, inward strabismus and contracted pupils. His lips were bright red, cheeks flushed, knee jerks were absent, and there

were no sensory reactions. He was cold and his teeth chattered, but there was no distinct rigor. After three hours he recovered consciousness but was drowsy, with an intense headache, pain in the stomach, reflexes still absent, but strabismus less marked. He made a complete recovery. Petrie (7) tells of a chauffeur who fell into a tank of petrol which he was emptying, but was rescued almost at once and suffered no permanent injury, although he was wildly delirious for a time and when he came to himself was not able for hours to speak intelligently, was very irritable, and suffered from intense headache.

Occasionally a severe case may occur among the men employed in the churning rooms of a rubber factory; for when many different kinds of cement are used the churns have to be cleaned out and the fumes of naphtha may be heavy enough to overcome the workmen who do this. Another place where severe naphtha poisoning may occur is in the dipping room where the men work over large tanks filled with rubber dissolved in naphtha and the temperature of the room is kept at 90° to 98° F. to hasten the evaporation of the naphtha. A case of this sort was reported to me by a physician in an Ohio town. The patient, a strong man, was found lying in bed comatose, with cold, pale skin, and almost pulseless. He had been dipping wooden forms of gloves into a tank of naphtha-rubber solution and had felt so dizzy and ill that he was obliged to leave work and go home, but on the way home he began to stagger and would have fallen had not two men half carried him. He was put to bed and not till then did he lose consciousness. His illness lasted several days, but he recovered completely, never, however, venturing to go back to that kind of work.

A personal communication from H. L. Lewis of the St. Lawrence State Hospital, Ogdensburg, N. Y., told of a case of acute benzin poisoning of unusual severity. The man, 30 years old, had worked in a shade cloth factory for two weeks with his hands in benzin much of the time, and breathing benzin fumes. At the end of the first week he had headache, dizziness and nausea, and after another week he suddenly developed an acute hallucinosis, seeing daggers sticking from the walls and imagining Italians were after him to murder him. In his terror he cut his throat, but the wound was not serious. There was no history of alcoholism, much as the symptoms resembled those of alcoholic hallucinosis. He made a complete recovery.

Dorner (8) reports a case which, because it had lasting results, was one of the most serious in the literature. A man was set to dipping crude benzin and fell into the tank where he lay for twenty minutes with his right side immersed in the benzin. He was, of course, quite unconscious when removed and lay in coma for three days. After that there was increasing loss of power in the legs,

especially the right. Dorner, who saw him seven months after the accident, believed that the lesion was in the pyramidal tracts with some involvement of the lateral and posterior.

According to Haggard (2), one of the members of a rescue crew of the U. S. Bureau of Mines entered a gasoline tank while wearing the half-hour type of oxygen apparatus and died. Experiments by Fieldner, Katz, and Kinney (9) showed that 2 to 2.5 per cent of gasoline vapor when mixed with a high concentration of oxygen in the breathing apparatus makes a man dizzy and is soon intolerable. But, toxic as it is, gasoline vapor is much less dangerous than carbon monoxid, and in cases of illness which develop in garage work the carbon monoxid is usually to be held responsible. There are, however, some cases which have been attributed, and with apparent reason, to gasoline fumes. Thus, Johnson (10) describes the poisoning with such fumes of 42 workers in a tunnel in Montreal who were using a gasoline engine to drag out rocks. Two men were asphyxiated, unconscious for twenty minutes, the face extremely flushed, pulse 100 to 108 of good volume and tension, respirations deep, 36 a minute. The patellar, plantar, and cremasteric reflexes were absent; the pupils were moderately dilated. On first regaining consciousness they could move their limbs but not speak; later they complained of severe frontal headache but of no nausea or vomiting. The next day they showed no effects. On another day 16 men were affected, and the following day the same 16 and two more. Some of them were as if in the second stage of anesthesia, others were weak with headache, salivation, brief unconsciousness. Two had clonic spasms. A spectroscopic examination of the blood showed no CO hemoglobin, and the air in the tunnel contained no carbon monoxid, but only gasoline.

Chronic Benzin (Naphtha, Gasoline) Poisoning.—Acute cases of benzin poisoning are striking, but chronic cases which attract less attention are not only far more numerous but usually more lasting in their effects. Chronic naphtha poisoning is probably common, but is not easy to diagnose because it does not produce characteristic symptoms. Many physicians practicing in rubber centers refuse to admit that there is such a thing as chronic naphtha poisoning, holding that the ill-health of rubber workers is to be explained on other grounds,—indoor work of an exhausting character or faulty personal hygiene. A rather significant report was recently made by the U. S. Public Health Service which found that a group of 22 persons operating a coupon-cancelling machine and exposed constantly to the fumes of gasoline used in cleaning stamps and belts, had a very high dispensary attendance rate in comparison with a control group. There was a mild, chronic poisoning from gasoline fumes and after kerosene, perfumed with anise, was substituted, the sickness rate was lowered and the output increased.

In the course of a study of the rubber industry I found many cases of what seemed to be chronic naphtha poisoning in the records of the Occupational Disease Clinic of the Massachusetts General Hospital of Boston, which city is a center of rubber manufacture. These histories showed a loss of health which seemed to be connected with the employment, a loss of vigor and energy, more or less headache, or simply oppression in the head, listlessness and dullness, restless sleep, loss of appetite, disturbed digestion, gastric pain, constipation. One man was sleepy all day while at work but could not sleep at night. Sometimes dry throat and a tendency to cough was the chief complaint. Less common were numbness or paresthesias or loss of muscular power. I saw a man in an Ohio rubber factory who had been making dipped rubber goods for three years. He was very anemic and for some time he had been increasingly nervous, had had attacks of dizziness, and was losing power in his right arm.

There are a few striking instances of chronic poisoning in the literature, the most famous of which were described by Dorendorff (11) of Berlin. These were in four men employed in rubber manufacture who suffered from lancinating pains in the limbs, coldness and numbness of the hands, loss of strength, loss of memory, and in one case, difficult speech. Potts (12) tells of a man who for four months had filled automobile tanks with gasoline. One day he fell unconscious and when he came to himself he had localized paralysis and a cerebellar gait. He was left with a permanent weakness of the third nerve on the right and with incoördination of the left arm. Peters (13) tells of a retro-bulbar neuritis following repeated exposures to benzin fumes, and Soupault and Français (14) tell of polyneuritis in French glove cleaning women who use benzin and petroleum ether.

The oil fields at Baku are productive of much poisoning, according to Korschenewsky (15) who found chronic bronchitis and anemia very common, not only among workmen but also among officials. Petkevitch (16) also describes cases of chronic anemia and nervous disease among these men. Goldschmidt (17) quotes Dujardin-Beaumetz as saying that gasoline fumes may cause pulmonary hemorrhage in the tuberculous.

Haden (18) of Johns Hopkins described a striking case of slow benzin poisoning. The man was 42 years old and for about thirteen months had been cleaning lithograph rolls by dropping them into a benzin trough 6 feet long and 1 foot wide. He used two gallons a day, all of which evaporated, and although the workroom was large there was no ventilation for fear the inks would dry. At the end of two months he suffered from nausea, vomiting, dizziness, sense of confusion in the head, and increasing weakness. As he grew worse, he was able to work only four days a week, and he grew so drowsy that he would have to wash his face in cold water to keep

awake, his legs felt heavy "as if they were bags of cement" and cold "as if menthol had been rubbed on," he had pains and muscular cramps in hands and arms and dimness of vision. He was so weak that it took him an hour to walk home instead of fifteen minutes, and several times he fell in the street. Haden found him so dull that it was hard to get his history; he seemed not to think clearly. His skin was jaundiced, his lips purplish, his breath had a sweetish odor, there were tremors of eyelids and tongue, and active reflexes. The liver was enlarged and tender, and the urine was almost black with bile coloring matter. There was a slight leucopenia at the expense of the polymorphonuclears, the red cells numbered 4,300,000, the hemoglobin was 70 per cent. The man improved rapidly under treatment and removal from the benzin fumes.

More recently Kraus (19) of New York reported a case in which unusual symptoms developed after exposure to gasoline and to the exhaust gases from a gas engine. The man began to work in August, 1920, and entered Bellevue Hospital in June, 1921. At that time he was troubled with numbness, weakness and coldness in the legs, hands and forearms. This trouble had begun the previous February when he suffered from dizziness, some nausea, frontal headache and general malaise. His legs slowly became weaker so that by April he could not walk. He had no other symptoms.

Examination showed no change in the cranial nerves. There was a diminution of sensibility in the legs almost to the knees, and in the toes there was a slight loss of sense of position. He was unable to stand. Later, at the time the report was written, he showed marked atrophy of all extremities, but no fibrillary twitching, no sign of involvement of any of the other nerves, and his superficial reflexes were still present. Six Wassermann tests were made of the blood, and three of the spinal fluid, and all were negative. Kraus does not hazard a decision as to the cause, which he believes may have been either gasoline or carbon monoxid. (See page 378.)

The lesions caused by the heavier distillates for the most part are confined to the skin.* Kerosene which is used to clean oily machinery and old type and the rolls of printing presses is less irritating than some of the heavier oils, but may cause enough acne or eczema to be quite troublesome. Still more trouble is experienced in connection with the lubricating oils, the highest boiling fractions before the paraffins and vaselines are reached. These

* An unconfirmed statement was made in 1888 by Mitchell (21) with regard to a form of acute poisoning which he had observed at Point Breeze and which he said could be attributed only to the breathing of oil fumes. Men who loaded barrels of kerosene oil on ships lying at the wharf would, after several days' work, be seized with cramp-like pains in the stomach and intestines, together with severe constricting pain about the lower part of the chest, with diarrhea, slight but obstinate, nausea and occasionally vomiting. The affection yielded to simple treatment.

lubricating or cutting oils are a prolific source of skin lesions in machine shops. There is irritation of the ducts of the sebaceous follicles, swelling and closure, with clogging and resultant inflammation which may eventuate in a general furunculosis. (See chapter 29.)

Petroleum in Industry.—The petroleum distillates are extensively used in industry for fuel and as solvents for fats, gums, resins, rubber, gutta-percha, and as illuminants and as lubricating oils. Those distillates whose boiling point lies between 30° C. and 90° C. are used for motor fuel and are known as gasoline. Between 70° C. and 150° C. come petroleum ether, naphtha, and benzin, for use as solvents. From 150° C. to 270° C. are the boiling points of the kerosenes, illuminating oil or coal oil, and over 270° C. come lubricating oils, vaseline, and paraffin. Oils from different parts of the world differ in the proportion of lighter and of heavier distillates. All are somewhat toxic and the presence of sulphur compounds in crude petroleum adds to the toxicity (60).

The pumping, refining and distilling of these oils has gone on for many decades in the United States, yet there is singularly little in the literature to show that the petroleum industry, as such, has ever given rise to industrial poisoning. Indeed, the first mention of skin lesions and of poisoning from fumes, sometimes fatal, in connection with the refining of oil in this country came from Berlin. Lewin (5), one of the foremost German toxicologists, came to the United States and in 1888 published in Germany an account of his investigation of the oil wells of Pennsylvania and the great refinery at Point Breeze on the New Jersey coast. This article aroused the interest of some American physicians and that same year saw the publication of reports by Mitchell (21) and Sharp (22), both of whom practiced in oil centers.

Lewin found that as a usual thing workers in petroleum refining suffered no impairment of health, but if a man were obliged to enter a tank he might lose consciousness and when removed he would be cyanosed, his eyes staring, pupils contracted, lips frothing, his pulse slow and weak, respirations slow, temperature lowered. There were many cases of this kind at Point Breeze but only one man died. Other cases of poisoning occurred in the filling of casks. Sharp had practiced for nineteen years in an oil town. He said there was no risk from inhalation of heavy oils but that light oils killed by suffocation. Three men had recently died in this way in the sheds built over oil tanks. Other cases of death, which always was very sudden, occurred around the wells while drilling was going on.

The large users of the lighter distillates,—benzin, naphtha, gasoline, petroleum ether—are rubber goods manufacturers, especially those making spread goods and dipped goods (see page 528), painters who apply quick drying paints in interior work or in factories, and

dry cleaning establishments. Hayhurst (23) found 33 cases of naphtha poisoning in Ohio factories, distributed as follows: painting and enameling, 9; rubber goods, 9; dyeing and cleaning, 7; varnish making, 4; cementing and finishing shoes, 2; shellacking, 1; scrubbing electrotype plates, 1.

In 1912 there was a widespread complaint among the painters in Cincinnati from the use of certain brands of flat-finish, quick-drying paints in interior work, and at the request of Dr. John H. Landis, Health Officer of the City, I made an inquiry into the nature of their complaint. It appeared that the painters had been working in a cheap apartment house where the tiny kitchens had no outside windows. The air grew so heavy with fumes, especially on damp days, that they could work only two hours at a time, when they were obliged to go out on the fire escape for an hour to get over the headache, dizziness, and choking, and the smarting and watering of their eyes. They lost appetite and some of them complained of nausea and vomiting. Pain of a colicky character in the region of the navel was the complaint in five cases, while three men complained of pain along the margin of the ribs and three of pain in the lumbar region. Sleep brought no refreshment, the men felt as if they had worked all night, and toward the end of the day they could no longer do the finer work, although in some cases the weakness, nausea, dizziness, and spots before the eyes were experienced when the man first went into the open air. Analysis of these paints showed no lead but benzin with about 20 per cent turpentine (4).

More recently the Workers' Health Bureau of New York City sent me a complaint from ten painters in that city who were using in interior work a turpentine substitute which proved to be petroleum ether. The symptoms were those of a local irritant and of a general toxic agent: congestion of the conjunctiva, burning, watering and bleeding from nose and throat, bronchial catarrh with cough, which dated from the beginning of the job, with marked air hunger. There was also dizziness, headache, confusion, sense of weakness, loss of appetite and irregularity of intestinal action. Some men also complained of frequent urination.

Dry cleaning establishments in this country are of two kinds—wholesale or retail. The retail establishments handle women's lighter clothing, curtains, gloves, etc.; the wholesale, chiefly men's clothing, women's heavy clothing, and bedding. Naphtha is almost universally used by both. Benzene was introduced into many plants just after the war, but the risk from explosion was too great and it was given up. Several owners also decided that it was dangerous for the employees. It costs a little more a gallon than naphtha and only a very few plants now use it.

The clothes to be cleaned go into a laundry washer, rotating, with naphtha for 20 or 30 minutes. The dirty naphtha is drawn

off, the clothes are wrung in a centrifuge, then fresh naphtha is run in and they are rotated for 10 to 20 minutes and wrung again. The naphtha goes to underground tanks, is passed through a clarifier which is like a cream separator, and is then distilled. A down draft is required by law to obviate fire risk. It is said by the men engaged in the trade that the fumes of naphtha are not allowed to escape, both because of the waste and of the fire risk. No cleaning by hand is carried on, not even of kid gloves.

The heavier distillates, with their effect on the skin, are discussed in the following chapter.

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CHAPTER 29

OIL FURUNCULOSIS AND TAR CANCER

Tar, Pitch, Paraffin, etc.—The literature concerning skin lesions in workers with coal-tar and petroleum oils, paraffin, vaselin, soot, pitch, shale, etc., is very confusing. It is impossible in most instances to gain any clear idea as to just what substances are playing a part in the acne, furunculosis, warty growths, keratomatous plaques, or cancers, which are described, and often it is hard to make out whether the skin lesions are due to chemical irritants or are caused simply by mechanical agents, such as the plugging of sebaceous ducts or injury by sharp bits of metal with subsequent infection. The phrases "shale oil," "coal-tar oils and paraffins," "pitch," "lubricating oils," cover a wide variety of compounds. Some of them, as for instance the low boiling petroleum distillates and coal-tar distillates, are strong solvents for fat, and by continually dissolving and removing the oils of the skin render it abnormally dry and then produce scaling, and perhaps cracking, which opens the way to infection. The use of benzene or benzin to clean oil from machinery or to remove paint and varnish often causes a dermatitis which is apparently of this character. Others, such as so many of the lubricants used in machine shops, seem to produce their effect by closing the sebaceous ducts and at the same time harboring and carrying germs of suppuration which bring about abscess formation. Still others, and just which is as yet unknown, seem to act as auxetics in the production of skin cancer, which supervenes after long stages of warty growths or keratomatous plaques or slow and obstinate ulceration. Much work remains to be done before we shall know just which chemical bodies are responsible for these lesions, but some progress has already been made in clearing up the confusion.

In the first place the cutting oils, lubricants, which in the United States are made from high boiling petroleum fractions, have, according to our present knowledge, no directly irritating action. Mitchell (1), in 1888, wrote the first American article on the skin lesions of oil refining men at Point Breeze. He saw many cases of generalized acne or furunculosis in men who worked with "paraffin oils." The heavy, tarry residue left after the removal of the gasoline, naphthas, and kerosene, is distilled again and yields

the so-called paraffin oils, which are first purified with sulphuric acid, then neutralized, and then put through hot presses and finally through a cold press to rid them of the solid paraffin. It is in the final stage of expression of the oil that the men suffer most. They must carry the oily paraffin to the presses and in doing so the skin of their arms and the clothing covering the chest and abdomen become saturated with oil. The eruption appears on the flexor surfaces of the arms, on the front of the abdomen and the thighs, wherever the paraffin has pressed the oily clothing against the skin. Similar lesions occur in men in the oil fields who work the pumps and get splashed with crude oil.

Lewin (2) also stated that the heavier the oil the more damaging to the skin. He saw men in the Pennsylvania oil fields handling crude oil and when it came in contact with the skin there were pimples and boils from inflammation of the sebaceous glands, closure of the ducts and infection with pus formation.

Cutting or lubricating oil rashes are of two kinds. One kind is due to plugging of the ducts of the sebaceous glands around the roots of the hairs on the hands, arms, and legs by a mixture of oil and dirt. The blocking causes inflammation around the hair, a pimple or "blackhead," and, if germs of suppuration gain access to it, a boil or abscess forms. The second kind follows injury to the skin by tiny particles of metal in the oil which lodge between the fingers and cut the skin or are caught in rags and waste and cut the man as he wipes his hands. These minute cuts inflame and suppurate because of infection by germs in the oil.

It has long been a matter of common knowledge that oil folliculitis and furunculosis was worse in some machine shops than in others. In 1917 Marvin Shie (3) of Cleveland published an interesting study of wound infection among workers in a manufacturing plant where infected cuts and multiple furunculosis were very common among the lathe workers. These men used cutting oils, while in the men using lubricating oils the lesions were for the most part no more serious than pimples. Cutting oils are usually a mixture of animal fats, petroleum oil, fatty acids, and water, mixed to form an emulsion which flows continually over the cutting tool and over the object in the lathe down to a reservoir and then is pumped up to a tank and flows down again, thus being used over and over. Shie found that these cutting oils harbored large numbers of staphylococcus aureus and cultures made from the furuncles and infected wounds yielded the same organism, while the lubricating oil proved to be sterile. He advocated disinfection of the oils by cresols.

A great advance in the prevention of wound infection and furunculosis from cutting oils was made by the Research Staff of E. F. Houghton and Company, Philadelphia, 1920, who found that while

all cutting oils have the power of penetrating the skin (especially hairy skin), and carrying in bacteria, there are certain ones which are especially harmful because they favor the growth of these bacteria more than others, and become more heavily contaminated by ordinary machine shop use. These are the oils commonly known as paraffin oils, which are not recovered by distillation but by pressure from residue matter from the stills. This confirms what Mitchell asserted in 1888. They found that the workers in the pressing plants of paraffin wax manufacture suffer quite commonly from epidemics of bacterial skin infection. The prevention* seems, therefore, to depend on two factors—proper selection of the oil for the lubricating mixture and strict personal cleanliness of the operatives. They do not believe in adding disinfecting chemicals to the oils, but find the use of a carbolized ointment on the skin of distinct advantage.

The skin cancers caused by paraffin oils, pitch, tar, soot, shale oil, briquette mixtures, etc., have interested surgeons and pathologists in Great Britain and Europe for many years and are still exciting the liveliest discussion.

Percival Pott,† in 1783, first called attention to the great prevalence of scrotal cancer in chimney-sweeps and asserted that it was caused by some tumor-exciting substance in the soot with which the sweep's body was covered. The lesion begins as a painful ulcer with hard raised edges, "soot wart," then it penetrates the scrotal layers, attacks the testes and may even grow into the abdominal cavity. It is of slow formation, in character a squamous-celled epithelioma, and is seldom accompanied by metastases. Soon after Pott's article, Earle called attention to a characteristic feature of chimney-sweeps' cancer, namely the early age at which it appears, usually between 30 and 40 years, and often even earlier. Astley Cooper then became very much interested in the cancer of chimney-sweeps, calling it one of the most extraordinary of human ailments. He observed some instances of cancer of the cheek in these men, and Paget saw cancer of the ear in men who carried bags of soot on their shoulders.

Curling called attention to the fact that the soot wart is at first a benign growth and later undergoes carcinomatous degeneration, and also that the action of the soot seems so to change the tissues as to produce in them a tendency to tumor growth, so that many years later there may be a secondary growth. In one of Pott's cases, a chimney-sweep had five tumors in twenty-one years, and Paget had

* A good summary of proper machine shop practice for the avoidance of skin infection from the use of cutting oils may be found in a bulletin written by F. E. Deeds in 1919 for the U. S. Department of Labor.

† A very exhaustive paper by Leutenberger (*Beitr. z. klin. Chir.*, 1912, 80, 208), contains the history of research in the field of chemical agents as cancer producers up to 1912.

a patient who came back for a second operation thirty-one years after the first.

Butlin, in 1892, made a thorough inquiry into the occurrence of chimney-sweeps' cancer and found that it was almost confined to Great Britain. British chimney-sweeps had a mortality rate from malignant tumors eight times the average for males of working age. On the other hand, Warren of Harvard informed him that American surgeons were not familiar with chimney-sweeps' cancer, and the same statement was received from French surgeons. In Germany the first case was reported in 1873 in Hanover, soon after the use of anthracite coal was introduced. Butlin concludes that the English chimney-sweep suffers from scrotal cancer because of something in the soot from hard coal. He admitted that this kind of coal was also used in northern Germany and in Belgium, in which countries scrotal cancers were very rare, but he believed that English sweeps were much filthier than Belgian and German, and therefore suffered more from the soot. (See page 416.)

Evidence has gradually accumulated pointing to the presence of some cancer-provoking substances not only in certain kinds of coal but in petroleum oils and coal-tar oils and pitch and paraffin. About the middle of the last century the distillation of shale was undertaken in West Lothian, and for the last fifty years Scottish physicians have been familiar with cutaneous cancers of the scrotum and arms in shale workers. Shale is a black non-crystalline substance like pitch, yielding on distillation ammonia, naphtha, illuminating oils, lubricating oils, and paraffin. The first cases reported in Scotland were two which came under the observation of Joseph Bell of Edinburgh in 1876. However, one year earlier three German cases had been reported by Volkmann (4), who in 1875 described cases of scrotal cancer in men producing illuminating oil from brown coal near Halle where this work had been carried on for fifteen years. Since then all such cases occurring in Germany have come from that locality, while the English cases have come from West Lothian.

In the United States much less is known of this so-called "paraffin or tar cancer," perhaps because neither chimney sweeping nor briquette making is an important occupation in this country. B. F. Davis (5), in 1914, reported a typical case in a Hungarian laborer who had worked in a large oil refining plant near Chicago. The oil with which this man came in contact was that described above, the oil pressed from crude paraffin. In addition to boils, the men in this department sometimes develop pigmented spots which may be scaly like psoriasis, then wart-like growths, and finally a true epithelioma as in Davis' case. The chemist of the company, answering the question as to the composition of these oils, said that about 90 per cent consists of completely saturated members of the paraffin

series, $C_nH_{2N} + 2$ (which bodies are inert), but that the remaining 10 per cent is composed of unsaturated bodies, C_nH_{2N} , which may act as irritants.

Among the few observations made by Americans in this field is one by McCord and Kilker (6) who had under observation a force of 17 workmen in a wood preserving industry where tars, creosotes and zinc chlorid are used. These men had the following lesions of the skin:

- “(a) Tar Dermatitis.—Dermatitis venenata, attributable in part to preparations used by employees in ‘cleaning up,’ such as benzene, light and heavy oils from coal tar distillation, and in part attributable to coal tar distillation products in the tar employed, was observed in only two cases.
- “(b) Tar Acne.—This condition was noted in varying degrees among all the employees examined. It is a common disease among all tar workers and is due to the accumulation of tar in the hair follicles, especially those of the forearms.
- “(c) Tar Cancer.—In two cases lesions were exhibited suggestive of tar workers’ or ‘chimney-sweeps’ cancer. One of these lesions was situated on the scrotum, and the other on the forearm. The quick disappearance of these lesions under treatment makes one hesitate before making a diagnosis of tar cancer.”

Southam and Wilson (7) found that in Manchester, chimney-sweeps’ cancer under modern industrial conditions no longer affects chimney-sweeps but a new class of workers, the mule spinners in cotton mills. During twenty years, from 1902 to 1922, no less than 69 of the 131 cases of scrotal cancer treated in the Manchester Royal Infirmary were in mule spinners. The next largest class was tar and paraffin workers, with 22 cases. There was only one chimney-sweep. The fact that the cancer in mule spinners was usually on the left anterior aspect of the scrotum led these authors to investigate the conditions under which the men were working, and they found that much of the time the mule spinner is leaning with his left groin pressed against a steel bar which is covered with oil and his clothes at this point are soaked with oil so that the skin is constantly irritated with a paraffin oil. The growth begins as a wart, but if it is removed even at this stage there may be malignant deposits in the groin twelve or eighteen months later. The warty stage persists for four or six months, and then typical ulceration begins. The cancerous growth is slow, metastasis into the inguinal glands is common, but in only one case did the growth spread to the peritoneum.

Leitch (8) in a recent article sums up what is known about so-

called paraffin cancers as follows: They follow long exposure to action on the skin of crude mineral oils and, although they are called paraffin cancers, it is not at all certain that the harmful agent is a member of the paraffin series; for Scottish shale and German brown coal yield olefins, naphthalene, and aromatic compounds. Workers in refineries who deal with the more refined oils or with the solid paraffin are not prone to tumors of the skin or to dermatitis. These skin cancers are all of similar type and occur on sites unusual unless associated with definite forms of irritation. They are frequently multiple, usually preceded or accompanied by warts or other hyperplasias, often of low degree of malignancy, and it usually takes several years of exposure to the noxious substance before they develop, never less than ten years in German industry and probably never less than fifteen years in Scottish oil works.

Experimental skin cancer by the external application of coal tar was first successfully produced by Yamagiwa and Ichikawa on the rabbit's ear, and since that time a large number of experimenters have produced such growths not only with coal tar but with the watery extract, the alcoholic extract, and the ethereal extract (9). Leitch has found that tumor growth, even carcinoma, may make its appearance some time after the cessation of the experiment, showing that the irritation produces in the normal cells some profound change undetectable by the microscope, so that they eventually proliferate in an unrestrained and harmful fashion. The exact constituent of coal tar which is responsible for this effect is not known. Bloch and Dreyfus (10) believe the active substance is in the anthracene fraction which boils over at 300° C. According to Legge (11), there is a decided difference in the action of various kinds of tar.

Epithelial ulceration in industry was first brought prominently to the notice of the British Commission on Compensation for Industrial Disease in 1907 when 38 cases among patent fuel workers of South Wales were reported to them. It is listed now under the Act as "Epitheliomatous Cancer or Ulceration of the skin due to tar, pitch, bitumen, mineral oil, or paraffin, or any compound, product, or residue of any of these substances." Patent fuel men apparently suffer most. Between the years 1911 and 1919 inclusive, 130 cases with 182 attacks of pitch warts and epithelioma needing treatment were voluntarily reported from the pitch, tar, and shale-oil industries. There were three deaths. In January, 1920, reporting was made obligatory, and during the next two years the cases ran as follows:

	Employed	Cases
Patent fuel industry.....	2500	49
Tar distilling and purifying.....	Probably over 2500	21
Shale oil	200	8

Blast furnace pitch was exempted from the special rules on the ground that in twenty-three years of distilling it, no case of skin disease had developed and that such tar was free from anthracene and naphthalene. According to Ross (quoted by Legge), the dangerous substance is not anthracene nor anthracene oil but some substance intimately connected with it and distilling over at the same temperature. Thus, pure anthracene oil is not mischievous but the commercial, rough, anthracene cake is.

Statistics from five Dutch briquette factories show the incidence of skin lesions among such workers. The lesions found were inflammation of sweat and sebaceous glands, flat and raised efflorescences, warts, and furuncles. Three hundred and ninety-five men were examined, of whom 138 had been employed less than one year. Lesions on the exposed skin were found in 96, on the covered skin in 17, and in both places in 9. Seven suffered from inflammation of the eyes.

The South Wales pitch workers show two kinds of skin lesions in the early stage, as described by Scholberg (12) of Cardiff and Sladden (13) of Swansea. The harmless one is a pendulous papilloma with a slender pedicle, often situated on the upper eyelids, present a long time and giving no trouble. The serious form is a flattened papilloma, slightly raised with broad base and smooth top, appearing singly or in groups, and at first the size of a small pin head. This form may increase rapidly, recur after cauterization, and unless excised become carcinomatous.

Ever since the year 1887 when Jonathan Hutchinson (14) presented before the Pathological Society of London six cases of epithelioma of the skin, which he attributed to prolonged administration of arsenical remedies, there have been recurring attempts to account for the skin lesions of tar and pitch workers on the ground of the arsenical content of the material they are handling. In Jonathan Hutchinson's cases arsenic had been administered for psoriasis and the skin cancer had been preceded by warts and keratoma of the palms and soles. Hutchinson said, "By the prolonged use of arsenic the nutrition of the skin may be seriously affected and amongst other changes warty or corn-like indurations may be produced, and if the drug be continued these 'arsenic corns' may assume a tendency to grow downwards and pass into epithelial cancer." Later Hutchinson endeavored to make arsenic in the soot responsible for chimney-sweeps' cancer, and arsenic in the beer responsible for the cancer of brewers and publicans and the frequent incidence of cancer in the general population. For a discussion of the subsequent literature on arsenical cancer the reader is referred to the chapter on Arsenic.

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CHAPTER 30

METHYL ALCOHOL

METHYL alcohol, CH_3OH , is known in industry under a variety of names—wood alcohol, wood spirit, methanol, methyl hydrate, wood naphtha, Columbia spirits, and Colonial spirits. The purified alcohol is colorless and has a taste and odor not very different from ethyl alcohol, but when it burns, the odor of formaldehyd is easily detected. Crude methyl alcohol contains much acetone, some ethyl-methyl ketone, methyl and dimethyl acetate, furfural, allyl alcohol, and other bodies that give it an extremely disagreeable odor and taste. It is this which is used as a denaturing agent for grain alcohol.

The effect of methyl alcohol is in some respects fundamentally different from that of ethyl alcohol,* although the action of a single dose upon animals is much the same for both alcohols. The symptoms, however, usually appear more slowly and the coma caused by methyl alcohol may continue for two or even four days, whereas that caused by ethyl alcohol never lasts as long as 24 hours. Even in the lower animals, therefore, methyl alcohol has a more powerful effect on the highly differentiated nervous structures, and it is a well recognized fact in pharmacology that poisons which affect these structures are proportionately more dangerous, the more highly developed the nervous system of the animal.

Ethyl alcohol is easily and comparatively quickly oxidized to carbon dioxid and water, while methyl alcohol is disposed of only with great difficulty. It has been recovered from the expired air over a period of seven days. Some is excreted into the stomach and is doubtless reabsorbed from this organ or from the intestines. It is slowly and incompletely oxidized with the formation of formic acid, which may not appear until the fourth day, and there is a profound disturbance of metabolism, a condition of acidosis and a marked increase in the excretion of lactic and other organic acids. Small repeated doses of ethyl alcohol establish a temporary tolerance, but methyl alcohol has a marked cumulative action. Even in cases which end fatally, distinct symptoms may not appear for from 24 to 36 hours, and in other cases recovery may seem to be well on the way when there is a sudden relapse and death.

* For the physiological action of methyl alcohol see the chapter by Reid Hunt and A. O. Gettler in *Legal Medicine and Toxicology* by Peterson, Haines and Webster, Philadelphia, 1923, p. 605.

Ziegler (1) says that methyl alcohol is the most deadly poison used in daily commerce. According to Lewin (2) the diagnosis is easily made; in fact, no industrial poison has a feature which is more characteristic than the blindness of methyl alcohol. This has occurred in a large percentage of severe cases of poisoning. As a rule, the vision becomes blurred and then there may be sudden complete blindness or partial blindness with a gradual improvement after a few days, which may last, but which is often followed by a second gradual failure of vision and finally by complete loss of it. Preceding the blindness there are always symptoms of poisoning, —depression, weakness and headache, fairly severe gastro-intestinal symptoms with pain, nausea, and vomiting. A history of disturbance of vision, especially variable vision, together with gastro-intestinal symptoms, is typical enough to lead to a suspicion of wood alcohol as the causative factor (Ziegler). In chronic poisoning the visual loss is more insidious and the diagnosis more difficult.

In industrial cases the very severest forms of wood alcohol poisoning have been seen, especially among men who use varnish with this solvent in small airless spaces. A few days' exposure was often enough to cause dizziness, intense headache, staggering gait, severe colic, nausea, vomiting, chilliness and cold sweats, blurring of vision or loss of sight, coma and death from failure of respiration, preceded often by convulsions. Von Jaksch (3) speaks of cyanosis and air hunger as ominous symptoms. The trouble with the eyes begins usually with pain and tenderness on pressure, slight photophobia, and spots before the eyes. The vision then becomes clouded, foggy, and the loss of vision comes on with concentric contraction of the visual field for both form and color. The pupil is dilated and sluggish and the sclera is congested. There is deep pain on rotating the eye, and there may be paralysis of the extra-orbital muscles, producing diplopia; of the muscles of the eyelid, which droops (ptosis).

The blindness has as its basis an atrophy of the optic nerve. De Schweinitz (4) explains blurring followed by temporary blindness, then improvement, and finally a gradual loss of vision, on the ground of an optic neuritis, an inflammation of the connective tissue of the optic nerve which subsides but is later followed by atrophy of the nerve. Ziegler says that the condition of the optic nerve head is a retrobulbar neuritis which is slow, followed by a decided shrinking of the nerve head, or a sudden sclerosis which occurs rapidly and has no appearance of shrinkage. On the other hand, Holden (5), who experimented with dogs, asserts that the blindness is dependent on nutritive changes in the ganglion cells of the retina; for he found, on using Nissl's stain, enough degeneration of these cells to account for the loss of sight. Friedenwald (6), who produced slow methyl alcohol poisoning in rabbits, also succeeded in producing marked degeneration of the ganglion cells of the retina.

Ziegler believes the primary and fundamental lesion in all cases of methyl alcohol poisoning is a profound injury to the pituitary body. He defends this by the history of a man who was poisoned by the use of methyl alcohol varnish in a small enclosure. "The changing, but steadily contracting visual fields, the fugitive scotomas, the visual loss and recovery, the sclerosed or atrophic nerve heads, the fixed and dilated pupils, the temporary paresis of the extra-ocular muscles, the ptosis, the ataxic gait, and the mental hebetude, are all characteristic of pituitary involvement."

The susceptibility to this poison varies very greatly. In the famous wholesale poisoning which was caused in a Berlin lodging house in the Christmas season of 1911 by brandy adulterated with methyl alcohol, some 130 men drank the poisonous liquor, 50 or more died, 42 became blind or had impairment of vision, while others who had drunk quite as much suffered only mild symptoms of poisoning. As much as from 48 to 72 hours in some cases elapsed before the poisoning made itself felt.

Loewy and von der Heide (7) found by animal experiments that as little as two parts of wood alcohol per thousand parts of inspired air will cause body saturation if continued long enough, and de Schweinitz (4) has observed that men can be exposed to fumes for long periods in the course of their work and then suddenly, without any increased exposure, develop toxic symptoms. In a case described by de Schweinitz, the varnisher had not only used methyl alcohol (Columbian spirits) in varnishing small ill-ventilated spaces, but had washed the varnish off his hands and arms with it at the end of work each day.

The manufacturer who uses wood alcohol, and the producer, have in the past always contended: first, that pure methyl alcohol is quite non-toxic; and second that it is impossible to produce poisoning even with the crude, except by drinking it. This last contention is not often made now; for there have been too many well authenticated cases among varnishers and other users who could prove that they had never drunk the solvent. Tyson and Schoenberg (8) of New York, questioning whether inhalation alone, without any absorption through the skin, could poison, experimented with rabbits, guinea-pigs, dogs, and one monkey, reproducing as closely as possible conditions in industry under which men have been poisoned. They found that repeated daily exposures to fumes of methyl alcohol caused reduction of visual acuity and marked reduction of general vitality. The injury produced was in proportion to the amount used, the humidity and temperature of the air, the length of exposure, and the susceptibility of the species of animal selected. Monkeys are much the most susceptible. Tyson and Schoenberg examined the blood and the aqueous humor of the eye of the animals. The blood was acid to phenolphthalein, viscosity and specific gravity were increased,

and coagulation time decreased. There was increase of red corpuscles up to 7,800,000, and of hemoglobin, and increase of polymorphonuclear whites at the expense of the lymphocytes, which had almost disappeared. The aqueous humor, which normally is neutral, was acid to phenolphthalein,—even more so than the blood. All these changes were produced by pure methyl alcohol as well as by Columbian spirits.

The question of the toxicity of pure methyl alcohol was settled conclusively by Reid Hunt (9) in 1902, though the superstition still survives among manufacturers that the pure is harmless. Hunt declared that though in certain commercial alcohols the toxicity may be increased by the presence of large quantities of impurities, the toxicity of these impurities has been tested, and it is doubtful if in the most adulterated specimens they are present in sufficient quantity to cause death. In other words, while the toxicity of a preparation may be increased by these impurities, methyl alcohol is still the chief toxic agent.

Methyl Alcohol in Industry.—Methyl alcohol is especially an American poison, and it has probably done more damage in the United States than in all other civilized countries put together. It is no longer necessary to enter into an elaborate argument to prove the toxicity of wood alcohol; for the numberless cases of severe and fatal poisoning in the United States since the passage of the Eighteenth Amendment have established that beyond the possibility of denial. Even before prohibition there was an excessive number of accidents of this sort, and although the majority of them were not of industrial origin, there have also been more industrial cases in the United States from this source than in any other country. The reason for this is that up to recent years American industrial alcohol was almost always crude methyl alcohol, while in Europe it was denatured grain alcohol. The effort to introduce the latter in the United States was rendered impossible for many years by the opposition of the powerful wood alcohol producers, and it was not until 1906 that a measure was passed providing for revenue-free denatured grain alcohol. The credit for this success must be divided between the National Society for the Prevention of Blindness and the Danbury hatters, who went before the Ways and Means Committee of Congress with incontrovertible evidence of the harmful effects of industrial wood alcohol. The former presented a number of shocking histories of death or blindness in men who had used wood alcohol varnish on the interior of beer vats, and the Danbury men presented 75 affidavits attested by physicians, from men who had suffered impairment of sight or injury to health because of their use of shellac containing wood alcohol in stiffening felt hats.

According to de Schweinitz (4), the first American physician to

describe wood alcohol blindness was J. M. Ray of Louisville in 1896, and during the next two years cases were reported from New York, but none of these was industrial. Apparently the first cases of industrial poisoning caused by absorption through the lungs and skin, were shown before the Chicago Ophthalmological Society in 1899 by Casey Wood and his assistant, Patillo (10). These were the first instances of that form of poisoning with which we became very familiar in subsequent years and which occurred when men engaged in shellacking the interior of beer vats were given so-called Columbian spirits to dissolve the gum and thin the shellac. Columbian spirits and Colonial spirits were trade names for purified methyl alcohol, and the use of these names was strongly opposed by the Society for the Prevention of Blindness, because to Europeans "Cologne spirits" means grain alcohol, and when these trade names were abbreviated, as they often were, European-born workmen confused them with Cologne spirits.

Patillo's patients had been working in beer vats 20 feet in diameter and 11 feet high with only one opening, just large enough to admit a man's body. The first man worked for four days, during which time he suffered from headache, dizziness and nausea; then, on the fifth day, he noticed that there was a fog before his eyes, and the next day he suddenly went blind. As is usual in such cases, he had a slight return of vision in the next two weeks only to have it fail later, and when Patillo exhibited him he had practically no vision in the left eye and very little in the right. The second case was very similar, except that this man was more resistant and worked for two weeks before he, too, became blind. It was the first time they had ever used Columbian spirits instead of grain alcohol. These two men both had atrophy of the optic nerve. The same condition was described two years later by J. A. Hale (11), also of Chicago, whose two patients were employed in the same sort of work, applying methyl alcohol shellac to the interior of what Hale called large hogsheads which the men entered to do their work.

In 1904, two years before the Danbury hatters went before the Congressional committee, Wood of Chicago and Buller (12) of Montreal, published an extensive report on wood alcohol poisoning in the United States based on the histories of no less than 275 cases. Few of these, however, only eight, I believe, were industrial in origin. Later, in 1912, Wood (13) spoke of six more industrial cases, three of which were fatal and two of which resulted in complete loss of sight. Tyson (14) added three more, and said that Gruening had seen two, while Baskerville (15), the chemist, collected 64 cases of poisoning by the inhalation of methyl alcohol (16). In the winter of 1915 L. I. Harris of the New York City Department of Health gave me the histories of three victims, all varnishers of

beer vats, two of whom died and one of whom was made blind. The shellac contained 52 per cent of methyl alcohol by weight.

In 1915 Tyson and Schoenberg (8) stated that there had been reported in this country up to that time some 100 cases of poisoning by inhalation of wood alcohol and that this number probably represented only a small percentage of those that had actually occurred, but had either not been recognized or had not been reported. They believed that some two and a half million persons in this country were exposed to this poison in the course of their work.

Among the early industrial cases in this country was one reported by Hawes (17) in 1905. A workman, 53 years old, was profoundly intoxicated after three days' work in cleaning paint from old furniture and applying shellac, both paint-remover and shellac containing wood alcohol. He was semi-conscious, his speech unintelligible, his temperature 100, pulse 108, pupils dilated and not responding to light, and urine negative. When consciousness returned he could count the persons in the room but could not distinguish them. There was blurring of the disk in the right fundus, contraction of the arteries in the left. These symptoms cleared for a time, but in fifteen days he was totally blind with dilated pupils.

Recent medical literature contains two industrial cases reported by Ziegler (1) and one by E. V. L. Brown (18). Ziegler's first case was an instance of over-susceptibility to wood alcohol; for the man was exposed to the fumes for only about an hour a day, when he would visit a china cement factory. The second case is the one which Ziegler cites in defence of his view of the involvement of the pituitary body in wood alcohol poisoning. This man was a painter, 20 years old, who inhaled fumes during three days while varnishing the engine room of a submarine. The first day he suffered from dizziness, the second day he became hilarious, and at the end of the third day he was dizzy, and had abdominal pain and insomnia. Diplopia from paralysis of the external rectus, then ptosis and blindness appeared. The diagnosis of epidemic encephalitis was made. After three weeks his sight began to return; the pupils were unequally dilated, the left more widely, and reacted to light and accommodation; the nerve head of the right eye was pale, with a central excavation, a venous pulse, and fine vascularization of the disk; the left eye was paler, less vascularized, more excavated, and the veins were full and pulsating. There was slight nystagmus, exaggerated reflexes and the gait was curious but there was no ataxia in standing. The fields of vision were limited for form and color, without central scotomas. There was also marked mental hebetude, which improved under the administration of pituitary extract.

Brown's case was also in a painter. He spilled about a gallon of wood alcohol down his leg, soaking his clothes and filling his shoe,

and instead of stripping them off he let them dry on him. Toxemia developed, followed in a few days by blindness.

The production of wood alcohol is described in Special Bulletin, No. 86, of the New York State Department of Labor, published in December, 1917. Wood is subjected to destructive distillation in iron or steel retorts or ovens. The gaseous products pass over, condensing in their progress, and there should be no loss of these gases, but occasionally retort doors fit badly and the fumes of wood alcohol escape. The condensed liquid is neutralized with lime, the process being known as "making a tub," and if precautions are not taken at this stage the workmen may be exposed to dangerous fumes. These products of the destructive distillation of wood include pyroligneous acid, acetones, acetic acid, phenols, and methyl alcohol, and the lime is used to neutralize the acids and form lime salts which can be filtered off. The liquid is then put through further distillation and the methyl alcohol recovered, together with a quantity of the tar, which is one of the by-products and which collects in the still and must be removed from time to time. There is danger of escape of vapors in the still house and work there is specially dangerous during the winter months when everything is closed to keep the still house warm enough. At intervals of two months the workmen must enter the stills to remove the accumulations of tar, and there have been frequent cases of blindness, temporary or lasting, among men doing this work. The use of a gas mask or air helmet is urgently recommended. In some factories barrel filling is automatic, but in most of them only rubber pipes are used and fumes escape as the barrel is filled, endangering the man who must stand near as he fills the barrel.

The absence of legislation providing for revenue-free industrial grain alcohol for so long a period had as a result the intrenchment in industry of methyl alcohol. Because of this, the American manufacturer became accustomed to using wood alcohol for processes which in Europe are always done with denatured alcohol. His methods were based on the use of this solvent and it was hard to convince him that any other would work as well. One still finds that of two processes which are apparently almost identical, one is carried on by means of grain alcohol, and the other by means of wood alcohol. For instance, nitrocellulose in the form of gun-cotton is dehydrated for smokeless powder with grain alcohol, but if it is to be used for making celluloid it is often considered essential to dehydrate it with wood alcohol.

Wood alcohol is used extensively even now in the arts and crafts as a solvent for gums, dyes, and resins, as a basis for the manufacture of various dyes, and as a solvent for coatings which have cellulose nitrate as their base. Varnishes in which wood alcohol is used have the advantage of drying more quickly than those made with

grain alcohol. Wood alcohol is the more volatile, having a lower boiling point, it dries faster. Jeliffe (19) reported two cases of multiple neuritis in painters using a wood alcohol varnish. A case which was reported to the U. S. Bureau of Labor Statistics was in a painter who suffered from partial blindness as a result of using a varnish remover on the pews of a church in Boston.

Varnishes, however, are now made chiefly with denatured alcohol, while shellacs seem to contain much more frequently straight wood alcohol. Thus, the New York State investigators found wood alcohol used exclusively as a solvent for the shellac applied to lead pencils by women and girls in one factory, although in another, denatured alcohol was used for the same purpose. In the manufacture of picture frames they found wood alcohol extensively used in cutting the shellac. In the manufacture of hat frames in two establishments they found refined wood alcohol used to dissolve the shellac for stiffening the frames. Several Panama hat factories also were found in which wood alcohol was used to dissolve shellac.

Another industry in New York which uses wood alcohol is the artificial flower manufacture. The dyes used are chiefly alcohol-soluble anilin dyes and the method used is to dip the parts of the flower in the dyes and to hang them up to dry, when of course the solvent evaporates. Some dyes dissolve more readily in wood alcohol than in grain alcohol and even denatured alcohol is considered less satisfactory. The investigators analyzed the air in one factory and found two parts of wood alcohol per 10,000 volumes of air by weight. Among the women employed in this work they found twenty who were suffering from inflammation of the skin and conjunctivitis. The inspectors insisted on the installation of a hood, well enclosed, where the drying of dyed material could be carried on, and that the drying rooms be thoroughly ventilated by artificial means.

According to Tyson (8), ordinary ventilation is not enough in a workroom where wood alcohol is used; for clinical cases will develop unless at least three times the usual air space is allotted to the workmen. Exposure to vapor for an hour or two daily may not cause immediate effects, but gradually trembling, weakness, unsteady gait will develop.

The most shocking cases of wood alcohol poisoning, followed by death or total blindness, were in the varnishing of vats in breweries, and even the introduction of denatured alcohol did not put a stop to such accidents; for the New York Department of Labor notes two deaths and four cases of permanent blindness contracted in such work between 1915 and 1917. The use of wood alcohol in boot and shoe manufacture in Ohio was, according to Hayhurst's (20) survey in 1915, productive of five cases of poisoning.

An irritating effect on the skin and an irritation of the conjunc-

tiva are common causes of complaint by users of wood alcohol in industry. Koelsch (21) attributes the affection of the skin to the action of alcohol in removing the fat from the skin; for there is no actual toxic effect.

The report of the New York Department of Labor for 1917 gives the histories of 16 cases of industrial wood alcohol poisoning which were investigated by the inspectors of the department. The first eight were in men engaged in varnishing the interior of beer vats. Five of them died after exposures of short periods, two days for Case 4, four days for Case 1. The other three were rendered blind, totally and permanently. A fourth man lost his sight as a result of the use of wood alcohol in some process in a copper refinery. Two less serious cases were in women varnishing pencils, who suffered from headache, dizziness and nausea, followed by dimmed and blurred vision. A gradually increasing impairment of vision resulted. The remaining five cases were in men working in the still house of a wood alcohol factory for periods running from three months to fourteen years. None was rendered totally blind, but all suffered attacks of temporary blindness or a gradual loss of visual acuity.

Apparently even the substitution of denatured alcohol for wood alcohol does not do away with all danger. Our law allows several formulas for denatured alcohol, but the substances used are almost always methyl alcohol and ill-smelling pyridin bases. Denatured alcohol usually contains 90 per cent grain alcohol, 9½ per cent wood alcohol, ½ per cent pyridin bases, but the law provides for the addition of as much as 20 per cent wood alcohol, and sometimes the formula calls for only 4 or even 2 per cent. German and Austrian denatured alcohol, however, contains only 2 per cent methyl alcohol and yet there has been so much complaint of ill health following the use of these mixtures (22) that both governments were obliged to appoint commissions of inquiry into the use of denatured alcohol in industry. The only report I have seen is that from Bohemia (23) and there it is stated that among men using a mixture denatured with crude wood alcohol, cases of amblyopia had developed. The report laid stress on the fact that crude wood alcohol was being used, containing not only methyl alcohol, but acetone, aldehyd, allyl alcohol, methyl acetate, and other volatile compounds more or less toxic; but the investigators admit that the effect of the methyl alcohol was undoubtedly predominant. The formula was like our Formula 2,—namely, wood alcohol 2 per cent, and pyridin bases 0.5 per cent.

J. M. Robinson of Duluth (24) reported a very interesting case of blindness apparently caused by the use of a black dye containing only 4 per cent of methyl alcohol. The man was working in a small shoe-shining and hat-cleaning shop, fairly well ventilated. He used a black dye, called "Colorite," for hats and not only breathed the

fumes from it but had his hands spattered with it about a quarter of the time. After five or six weeks of this work he began to notice that objects looked smoky, and at the same time he became easily tired, perspired freely, suffered slightly from nausea and a somewhat vague stomach trouble. When he went to Dr. Robinson these symptoms were more pronounced and he had headache and slight dizziness. At that time vision of the right eye was reduced, and that in the left eye was almost gone. There was congestion of the disk on this side. Later both optic disks became perfectly white, and when last seen the man was in excellent health, but totally blind.

Analysis of the Colorite, made in the Hygienic Laboratory of the Public Health Service, showed that the color was an anilin derivative, indulin, and that the vehicle contained 4 per cent methyl alcohol. There is no reason to believe that indulin could be responsible for an optic nerve atrophy, but every reason to believe that methyl alcohol could produce just this result; and though 4 per cent is an unusually small amount to cause trouble, yet we know that there is no poison so capricious in its action on the individual as methyl alcohol. The histories of the victims of the wholesale wood alcohol poisoning in the Berlin lodging house in 1911 showed that some men were killed, others blinded, and others only mildly intoxicated by the same amounts of brandy adulterated with wood alcohol.

Unfortunately the rules adopted by the Internal Revenue Department of the government are so framed as to encourage the use of the varieties of denatured alcohol which contain the higher percentages of wood alcohol. Recently in a dye works I went into the department where metanil yellow is manufactured and was told that they had had a good deal of illness among the men. The compound used is metanilic acid, which is coupled with diphenylamin in denatured alcohol. As the two former are practically harmless, the illness was attributed, and probably correctly, to the alcohol, which contained 10 per cent methyl alcohol. I was told that it would be perfectly feasible to use the formula containing only 2 per cent, except for the government regulations which are much more onerous in connection with the 2 per cent than the 10 per cent, requiring that the alcohol be kept in a bonded warehouse, that only specified quantities be taken out at a time, etc. It is very deplorable that the government should discourage the use of the safer formula.

That nitrobenzene may be used as a denaturant is shown by an epidemic of poisoning from drinking denatured alcohol to which this chemical had been added, described by Scott and Hanzlik (25) in 1920.

Koelsch found 12 per cent of the furniture polishers in one factory and 5.8 per cent of those in a second, suffering from skin disease.

He attributes it to the fat-removing action of alcohol and the irritating action of pyridin.

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CHAPTER 31

ETHER. ALDEHYDS. HEXAMETHYLENETETRAMIN.
METOL. AMYL ACETATE. DIMETHYL SULPHATE.
NITROGLYCERIN

ETHER

THERE is only one use for sulphuric ether in industry and that is in combination with alcohol in the making of smokeless powder and pyroxylin.* Guncotton, cellulose nitrate, is dehydrated and brought to a colloid state by means of ether-alcohol and then pressed and cut into appropriate shapes. It is in the pressing and cutting department, much less in the mixing which precedes it, that ether fumes are encountered and produce both acute and chronic poisoning. The first to discuss this form of industrial poisoning was apparently René Sand who, suspecting that the ether fumes in a large Belgian plant which he often passed must be the source of some disturbance of health among the workers, experimented on dogs, giving them ether-alcohol in vapor form, 500 gm. being evaporated during ten hours in a kennel one cubic meter in size. The dogs all exhibited symptoms characteristic of the early stages of ether anesthesia at first, but later on they gained a tolerance and did not seem to suffer in health, in fact three gained weight, but when two of them were killed it was found that the organs and brain were in a general condition of stasis, with fatty degeneration in the kidney epithelium and in the liver. Sand's paper was read before the International Congress of Industrial Hygiene in 1910.

During 1916 I investigated the smokeless powder plants in this country, nine of which were already making large quantities of the product for sale abroad. Only men were employed then but when we entered the war the place of men in the pressing and cutting department was taken by women, for the work is light and easy. By the spring of 1918 several hundred women were so employed. The investigations carried on for the Department of Labor and the National Research Council covered the men employed before our

* Smokeless powder is a product of low nitration, containing 11.5 to 12.5 per cent of nitrogen. High explosive powders, such as cordite, are made from nitrocotton of higher nitration, with 13.5 per cent nitrogen. These are mixed with nitroglycerin and sometimes acetone and vaselin, to form colloidal strips. These latter "powders" are not soluble in ether-alcohol.

entrance into the war, the women employed till the armistice and a small group of men who took their places after the armistice. Our findings can be briefly summarized.*

Ether work was not popular among powder men yet many said that they grew accustomed to it after a while and some never felt any effect from the fumes. The usual experience of susceptible men was what they called an "ether jag," that is a gradually increasing excitement, irritability, pugnacity or exhilaration, then confusion, drowsiness, passing into unconsciousness. In rare cases this was deep and prolonged, but usually the man slept it off, waking in the morning with headache, nausea, anorexia, pains in the lumbar region and general misery. A few men told me they had had to give up because of loss of appetite, obstinate constipation, a continual taste of ether and increasing apathy. I was also told by physicians that they had reason to suspect an action on the kidneys. One physician always granted a transfer to an ether man who had puffy eyelids even if he did not find albuminuria, and a severe case of nephritis was attributed by another physician to long exposure in powder pressing and cutting.

An interesting detail in connection with this ether poisoning was the marked effect produced on the powder men by alcohol. The men working over at Carney's Point opposite Wilmington used to cross to the city for drink and it was common talk in Wilmington that a few glasses of beer or a single drink of whiskey was enough to make a powder man dead drunk and that the ether on his breath would scent the air in the police stations and work-house.

The experience of the girls was like that of the men, but they seemed distinctly more susceptible to the ether and apparently the same thing was found to be true in British works, for the report of the Chief Medical Inspector of Factories and Workshops for 1918 says that the women who were introduced into smokeless powder works suffered so much more severely from ether fumes than the men that it was necessary to put men in their places. We made an intensive study of 80 women in one plant, during the summer of 1918. They were between 16 and 36 years of age, 39 being under 21 years, and 47 never having done any factory work before. They were admirably housed, fed and cared for, they worked only eight-hour shifts, yet they did not escape the effects of the ether. Forty-eight had had acute ether poisoning and 17 more suffered from dizziness and faintness, making 65 or 80 per cent of the whole. Seventeen of these had had more than one such attack. Among the group of 80 there were only 32 who had worked 6 months or longer and 16 of these complained of ill health which they dated from

*"Ether Poisoning in the Manufacture of Smokeless Powder." Hamilton, A., and Minot, G. R., *Jour. Indust. Hyg.*, 1920-21, 2, 41.

their work in ether fumes, the other 16 were not at all inconvenienced by their work, unless perhaps by an occasional dizziness or headache on a hot day.

One of the most common symptoms was loss of appetite especially for lunch, because the taste of ether was still in the mouth. A few girls had at first eaten ravenously, but soon after a distaste for food came on. Twenty complained of attacks of nausea but only seven had actual vomiting. Constipation was brought on or increased by ether work in 28. Only five had disturbed sleep but 31 complained of sleepiness, craving 12, 14 or even 15 hours sleep, practically all their spare time. An itching eruption, most marked on the side of the face nearest the cutting machine, was a symptom from which a few girls suffered.

Urinary analyses for sugar and albumin gave negative results except for three cases in which albumin was found. Only one of these was suffering from loss of health. She had lost weight during her seven months' employment, had lost appetite, and suffered from nausea and occasional vomiting, constipation and drowsiness.

The blood changes were studied by G. R. Minot but his investigation was cut short by the dismissal of the girls after the armistice and the effort to continue with the men who took the places of the women was not wholly satisfactory for the men were a selected group of immunes and not comparable to the former group. The striking change in the blood of the girls was a polycythemia, the red cell count running above 6,000,000 in over half, a number which is very high for working women. Control counts made on healthy young women in the same locality not exposed to ether varied between 4,700,000 and 5,300,000. The ether girls' counts were from 5.5 to 7 million in 38 out of 51 cases, from 7 to 7.8 million in 7 cases, and less than 5.5 million in only 6 cases. The white counts as a rule were above normal, from 6,800 to 16,000, averaging 11,000. There seemed to be no clear-cut relation between the polycythemia and symptoms of ether poisoning.

Minot examined also the blood of the 35 men employed after the armistice. Only 12 had a count over 5,500,000—the highest being two with 6.5 to 6.7 millions—the rest were between 4.6 and 5.5 million. A more careful examination of the red cells was made in these cases and in about 20 per cent abnormal cells were found, achromatic or of abnormal shape. The explanation for these blood changes in ether poisoning cannot be made without more study.

A very severe case of chronic ether poisoning in a smokeless powder factory employee came before the United States Compensation Commission recently and the diagnosis was made in spite of unusual complications. The man was exposed continuously for seven years to an atmosphere of ether fumes, then, since he complained

that his health was being injured, he was shifted but still for the next five years he was at times exposed to such vapors. When finally he stopped work because of serious illness he was found to be suffering from a severe form chronic interstitial nephritis. His general condition was very poor, the urine was almost solid with albumin when heated and full of hyaline and granular casts.

Shortly after, he suddenly developed an erythema nodosum which gradually changed to erythema bullosum and then quite rapidly into a typical pemphigus malignus, with blebs on nasal and buccal membranes extending down into the bronchi and finally a pulmonary edema, which was the direct cause of death. In the opinion of the medical examiners the man died from chronic nephritis, caused by the long inhalation of ether, and the pemphigus was closely related to the nephritis. No organism was found by staining nor by culture from the blebs.

ALDEHYDS

Acrolein.—There are two aldehyds which are important industrially. One of them is a troublesome by-product formed when fats are rendered in making candles and soap, in boiling linseed oil for the manufacture of varnish, and in melting down old printers' type covered with oily ink. This by-product is acrolein, acrylic aldehyd, $\text{CH}_2: \text{CH}: \text{CHO}$. The fumes are heavy, thick, and very irritating. In melting old type these fumes come off as soon as the kettle is heated, and by the time the lead fumes begin the fat has all been driven off. In stereotype foundries where the huge stereotype plates are melted down, these fumes have to be carried off by fan or by exhaust hood. Acrolein is so irritating and injurious that it was one of the gases tested by the Germans for use in gas warfare, but they did not adopt it. Iwanoff (1) tested three aldehyds: acetaldehyd, formaldehyd, and acrylic aldehyd, and found them toxic in that order. Animals exposed to 1.5 g. of acrolein for two hours developed irritation of the lungs with edema. Lewin (2) tested it on himself and found it irritating to the mucous membranes. It was possible to inhale it but his instinctive impulse was to hold his breath and keep it out. He had some dizziness and confusion and sense of pressure in the head. A longer exposure may cause distressing catarrh in the pharynx and bronchi, pressure in the stomach, pain, diarrhea.

Formaldehyd.—The other important aldehyd, formaldehyd, is made for use as a disinfectant. It is also combined with phenol to make bakelite, a substance very like hard rubber used extensively in the manufacture of telephone installations and other electrical goods. Formaldehyd is also combined with ammonia to make urotropin, which is hexamethylenetetramin, for medicinal use, and

for use as an accelerator of rubber vulcanization. Anilin formaldehyd, called Redmanol, is another accelerator. Formaldehyd is also used as an intermediate in the manufacture of dyes, especially of synthetic indigo.

Lewin found formaldehyd less toxic than acrolein. In human beings irritation of the respiratory mucosa is the most usual effect. Physicians in Perth Amboy, New Jersey, where formaldehyd and its derivatives are manufactured, see many cases of bronchitis and occasionally of broncho-pneumonia from breathing the fumes. A formaldehyd dermatitis occurs in susceptible men. Both bakelite and urotropin are irritating to the skin, and bakelite itch is common in Perth Amboy, although no trouble seems to occur from the handling of the finished product.

According to Brunnthaler (3), writing in 1914, the toxicologic importance of formaldehyd is not appreciated in spite of its widespread use. He insists that it has a cumulative effect analogous to that of wood alcohol, and like the latter it is slowly oxidized to formic acid. It is stored as a methyl compound and has a characteristic effect on the proteid molecule which explains its action in causing arterial necrosis. The irritating effect of the fumes produces the other side of the picture, which is a combination of the special toxic action and the irritant action. Under the head of the irritating action he describes the effect on the eyes which may result in an ulcerative process, on the respiratory mucosa throughout the whole tract, on the skin causing obstinate dermatitis. There may also be severe colics and the bronchitis may become chronic or may pass into pneumonia. He quotes Tommasi-Crudeli as having found lesions in liver and kidneys after experimental poisoning. Loeb (4) produced areas of necrosis in blood vessels followed by tiny aneurisms by the injection of formaldehyd. Brunnthaler calls attention to the fact that commercial formaldehyd always has some methyl alcohol, perhaps 12 to 20 per cent. The susceptibility of individuals varies greatly, but he believes that once poisoned the liability to poisoning increases.

Recently a complaint was made by several men using a certain hat bleaching fluid which they found caused an obstinate itching, burning, eruption on the skin with which it came in contact. The preparation was found to contain precipitated sulphur, talcum, glue, and formaldehyd, which last had been added to prevent the souring or putrefaction of the glue. The reaction was acid, showing that part of the formaldehyd underwent oxidation and changed into formic acid. The dermatitis was attributed to these latter substances and the manufacturers were advised to substitute sodium benzoate for the formaldehyd.

HEXAMETHYLENETETRAMIN

Hexamethylenetetramin, or urotropin known as "Hex" to rubber workers, is a fairly prolific source of troublesome dermatitis in that industry. Kratz (5) wrote an article in 1917 in a trade journal describing it as a rash which begins on the wrists, extends up the forearms, then appears on the face and neck, and in some cases spreads over the body. At first it is an intense erythema which soon becomes vesicular and then crusty, much like ivy poisoning, and it resembles the latter also in itching much more violently at night. It is however not obstinate, and if a man lays off work it subsides in a few days. Warm humid weather greatly increases its incidence and Kratz believes that the cause is to be found in exposure of the sweating skin to green stock (*i.e.*, stock not yet vulcanized), especially cotton fabricated stock, but also any form of uncured (unvulcanized) rubber.

As a result of this paper, a committee was appointed by the Rubber Section of the American Chemical Society to investigate the possible poisonous effects of the new organic accelerators of which hexamethylenetetramin is one. With regard to this compound they found that it does cause inflammation of the skin which has been in repeated contact with stock containing it, but that change of occupation will cause the rash to disappear leaving no permanent effects (6).

Shepard and Krall (7) tried to produce the rash experimentally in laboratory men, but were unable to do so even on a profusely sweating skin, although it appeared promptly in the factory as soon as the weather turned warm. They agree with Kratz that the rash is confined to the men handling "green stocks or liners" but they do not believe that there is anything in green stock which produces the rash except hexamethylenetetramin. The reason why vulcanized stock does not have this effect is that during vulcanization this compound reacts with sulphur and breaks up, forming hydrogen sulphid, carbon disulphid and a sulpho cyanid.

METOL

Metol is the trade name for mono methyl-p-amido-m-cresol sulphate. It was introduced from Germany in 1891 as a photographic developer (8), and in 1908 Beers (9) published an article on metol eczema in photographers. Karasek (10), of the Illinois Commission on Occupational Diseases, found 31 cases of metol eczema in his investigation of 40 photographic studios in Chicago. The eruption was on the hands and arms, and occasionally on other parts of the body, and in severe cases there were ulcers. Among the 4,142 cases of eczema of external origin reported by Knowles (9) were

768 of occupational origin and five of these had been caused by metol, four of the victims being photographers and one a photo-engraver. He says that the use of this compound is limited to these two occupations. Many of the men who have used it for years believe themselves to be immune, but Beers showed that they would succumb to the application of metol to the soft skin of the upper arm, a rash appearing within 48 hours. After an attack there seems to be a heightened susceptibility.

A case reported in a personal communication to the Journal of the American Medical Association in 1921 (11) was in a photographer who had suffered more or less from skin lesions since 1912 when he began using metol. He had large areas on the anterior surface of the left knee and groin covered with an eruption like "weeping eczema," and there were also lesions around the inner canthi of both eyes. In answer to queries the editors of the Journal described the appropriate treatment for metol eczema.

There is a note in a recent number of the London *Lancet* (8) to the effect that pure metol is free from the substance that causes irritation to the skin. W. F. A. Herman, working in the department of photographic research of the British Dye Stuffs Corporation, says pure metol is quite innocuous to the skin and that it can be produced by modifying the present method of manufacture.

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AMYL ACETATE

This substance, known as banana oil, is a very useful solvent and therefore an ingredient of celluloid, of cellulose nitrate coatings or "dopes," and of shellac and varnish and paint removers. It has a bad reputation among workmen, largely I believe because the heavy, penetrating and nauseatingly sweet odor is strong enough to cover up the odor of such solvents as benzene and wood alcohol and therefore when the workman begins to suffer from the ill effects of the mixture he is using he naturally attributes his trouble to the compound that produces the odor.

Amyl acetate was carefully tested in Germany by Heffter and Joachimoglu (1) in connection with their study of dope poisoning in airplane factories, but they found that although the animals which had breathed amyl acetate fumes showed some irritation of the eyes and lost weight, they recovered easily, and those that were killed on the ninth and eleventh days showed no anatomical changes. Lehmann (2) finds the same comparative harmlessness of this solvent. He could not succeed in producing complete narcosis in rabbits, and death did not follow even so large a dose as 35 milligrams per liter of air. There was a good deal of irritation of the mucous membrane of nose, throat, eyelids and bronchial tubes, and large doses produced alteration in gait and partial narcosis.

Two healthy young physicians, assistants in Lehmann's laboratory, breathed for half an hour air containing 5 milligrams of amyl acetate to the liter. They first experienced a feeling of irritation in the throat and nose and eyes, and then a dry burning in the throat, and a slight sense of weariness, but no headache nor nausea or change in the pulse rate.

Koelsch (3), who is in charge of the Department of Labor of Bavaria, made inquiries among the factory inspectors as to the effect of amyl acetate in workers with lacquers, metal varnishes, varnishes for frames, pencils and pen handles, and among bookbinders and leather workers. The inspectors reported that the compound seemed comparatively harmless, causing symptoms only in exceptional cases, and then no more than drowsiness, dizziness, and headache, cough, a feeling of tightness in the chest, and nausea. All these symptoms were worse in new men, as they quickly became accustomed to the vapors. They had no evidence of any chronic organic trouble resulting from the use of amyl acetate.

Koelsch himself interviewed five workmen, all dopers in an airplane factory using a dope made with amyl acetate and acetone. One of them complained of weariness and occasional sick headache which he attributed to the banana oil, but the others had never felt any discomfort from it. He then experimented on himself, breathing the vapor of heated amyl acetate, and he found that it produced a feeling of heat in the head, an inclination to cough, and a slightly increased pulse rate. A little later he grew dizzy, somewhat drowsy, and confused and tired, and his respirations became deep and quick. When he went home at the end of the experiment he found it difficult to mount the stairs. To test it further he exposed rabbits to an atmosphere containing 0.5 to 1 per cent. They showed symptoms of air hunger and nervous irritation which passed away quickly in the fresh air. He exposed guinea-pigs for many days, ten hours a day, to this atmosphere, and they developed marked nervous symptoms, ataxia and motor paralysis, but these did not persist after they were taken into pure air. After a long time, 237

and 340 days, they lost appetite and grew thin, and two that died were found to have edema of the lungs with areas of consolidation and fatty liver.

In an investigation of airplane doping during the war (4) I came to the conclusion that workers with amyl acetate may be expected to complain of smarting and running eyes, dryness of the throat, a feeling of tightness in the chest, and an inclination to cough. More rarely they may feel drowsy and unaccountably tired and vaguely nervous. Such symptoms as nausea, headache, vomiting, gastro-intestinal distress or anemia do not seem to be characteristic of amyl acetate poisoning, nor have we any evidence that chronic organic disturbances follow long continued exposure, though experiments on animals point to such a possibility.

The last report of the German Factory Inspection Service tells of the use in a Prussian factory of a substitute for alcohol in furniture polish which affected the men unpleasantly, giving them headache and a dry cough. It proved to contain amyl acetate, amyl alcohol, and propyl alcohol. An interesting report comes from France. Heim, Agasse-Lafont and Feil (5) describe the symptoms and blood findings in women who were employed in making small portable battery boxes of celluloid. They used two substances, celluloid powder containing camphor, and a sort of glue containing a mixture of equal parts of amyl acetate and acetone. They found one clinical symptom, headache, and one persistent and frequent blood finding, eosinophilia. They think that this latter change in the blood gives an almost indubitable proof of intoxication, or at least of a reaction to the saturation of the organism by fumes of acetone and amyl acetate.

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DIMETHYL SULPHATE

Dimethyl sulphate or dimethyl ester of sulphur, $(\text{CH}_3)_2 \text{SO}_4$, is used in dye manufacture, to produce the important intermediate, dimethylanilin, but it is not essential to use it, for if heat and pressure are provided, methylation of anilin may be effected by the less toxic compounds, methyl chlorid or iodid or alcohol. Dimethyl sulphate, however, can be used more cheaply and therefore it often is, although the danger attending it is generally recognized. It was

one of the gases selected by the Germans for possible use in trench warfare and their attention had probably been called to it by three severe cases of accidental poisoning in dye workers, two of them fatal, which were studied by Weber (1) in Schmiedeberg's laboratory. He found that the toxicity is due to the whole molecule, not to any group split off from it and that its characteristic action is an intense caustic effect on all tissues with which the vapor comes in contact, including the lungs. When absorbed, it differs from other ethers and esters by producing not only coma but convulsions. There is no possible antidote. The three Germans were poisoned by fumes and one of them also by spilling it on his clothes. There was severe inflammation of the mucous membranes of larynx, trachea and bronchi, with complete destruction in spots, intense inflammation of the eyes, bronchitis with subsequent pneumonia, and in the two fatal cases, hemorrhages into serous membranes and cloudy swelling of liver and kidneys.

Two American cases, less severe than these, were reported by Mohlau (2) of Buffalo in 1920. These men were also exposed to the fumes and suffered from inflammation of eyes, throat, and respiratory tract. One of them was delirious and then comatose and several times during recovery from pneumonia he suffered relapse with an aggravation of all symptoms. At the time of writing, some six weeks later, both were still suffering from photophobia and one had complete loss of color vision and his visual field was reduced to one-tenth.

A curious effect of dimethyl sulphate was noted by Auer (3) in experimental work on animals, namely a marked generalized analgesia, which develops in cats exposed to the fumes after a few hours and reaches its height in 24 hours, during which time severe operations may be performed without any sign of pain. If the animal recovers, the analgesia may still be well marked six months afterward.

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NITROGLYCERIN

Nitroglycerin, glyceryl trinitrate, $\text{C}_3\text{H}_5(\text{NO}_3)_3$, is an extremely active drug, the medicinal dose being one-half to two minims or 0.03 to 0.1 cc. of the one per cent solution. As little as one-fiftieth of a minim (0.001 cc.) has produced a most severe headache. (1)

Poisoning in industry occurs in the nitration of glycerin and in

the preparation of various explosives, dynamite and the mixed powders such as cordite and ballistite. In 1910 Laws (2) described under the name of "the nitroglycerin head" the industrial form of poisoning. There is at first a sensation of heat and fullness in the head, and possibly flushing of the face, the heart beat is rapid but later markedly slow. There may be blindness in one or both eyes, but as the headache begins vision clears up. The pain is intense, throbbing, so that stooping is intolerable and even lying down may be. The man may become literally mad with the pain and Laws tells of one man who was wildly delirious, rushing about, shrieking and hitting his head against the trees and wall; and of another, a mild-mannered fellow, who struck at anyone within reach. The pain may last only a few hours or as long as two days and nights. Nausea and vomiting accompany it and a loathing for food, and frequent and copious voiding of a low gravity urine. If the man is given alcohol he may flush all over and look as if he had scarlet fever.

Laws notes that "powder men" have a rapid heart on exertion, that they easily become intoxicated with alcohol, but he does not know what, if any, effect on length of life chronic exposure to nitroglycerin may produce. Certainly some men become quite immune to the effects and he has seen old hands who are strong and well. The poison enters not only through the air passages and alimentary tract but also through the skin and Laws believes it can be acquired by susceptible people simply by shaking hands with a powder man. Poisoning occurs in members of the family who handle the man's working clothes or who sleep in the same bed with him.

Evans' (3) case was in a farmhand who was blasting stumps with "giant blasting powder" and who began to suffer from throbbing headache after a week's work, nausea, vomiting and dizziness. An interesting proof that the nitroglycerin was the cause of his illness was furnished by the fact that all symptoms disappeared when he left his job, but recurred when he put on a pair of cotton flannel gloves he had worn when blasting, and did work which made his hands perspire freely.

Ebright (4) made an examination of twenty nitroglycerin men in the Du Pont Powder Company's plant at Hercules, California. He found natural immunity very rare, practically every man having had the very disagreeable experience of the "powder headache," but the degrees of exposure necessary to bring it on varies a good deal. Susceptibility seems to be increased by warm, humid weather. After three or four days' work with nitroglycerin a fairly high degree of immunity is established, but it is not proof against an unusually great exposure, nor does it last unless the man remain at work. A short vacation is enough to destroy it and therefore powder men often place a little nitroglycerin in their hat bands if they are to be absent for some days, so as to keep up their immunity. During

the war when I visited explosive works I was often told by my guide that the short exposure which was involved in showing me the "powder line" was enough to start up the familiar powder headache because the immunity gained by constant exposure was lost when a man came and went on other work.

Ebright noted no permanent effects in the men he examined but they were a selected group, not given to drink, not allowed to smoke on the job, and of course unusually resistant to the effects of the poison or they would not have stayed at work. There was no arteriosclerosis, nor abnormally low blood pressure, nor relaxation of the arteries or capillaries, and no glycosuria even during an attack. Alcohol would precipitate an attack in some men or increase its severity, as it did in a construction foreman who on a certain day handled over a ton of explosives and arrived at his lodgings in the evening with a splitting headache. He took quite a little whiskey for it and within two or three hours he had developed an acute homicidal mania, shooting right and left, wounding one of his friends and killing a bystander.

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CHAPTER 32

TETRACHLORMETHANE. TETRACHLORETHANE. OTHER CHLOR COMPOUNDS. METHYL BROMIDE.

TETRACHLORMETHANE

CARBON tetrachlorid, or tetrachlormethane, CCl_4 , is used in industry as a solvent for gums, resins, and fats. Since it is non-inflammable it is sometimes substituted for the inflammable carbon disulphid in the manufacture of automobile tires, and this same property leads to its use as a dry cleanser. It is also a constituent of some rubber cements, is used to clean oil from machinery, and, under the name of Pyrene, it is widely used as a fire extinguisher.

It is made in three ways, first, by the direct chlorination of ethylene; second, by the action of chlorine gas on carbon disulphid; and third, by an electric arc acting on a mixture of carbon and CaCl_2 , as a result of which CCl_4 and CaC_2 are produced. (*Chem. Zentralbl.*, 19, Vol. 2, 1411.)

During the sixties of the last century carbon tetrachlorid was tested by Richardson, Simpson, Sansom, and Nunnely, and by them recommended as a remedy for headache, neuralgia, and chorea. Such serious effects, however, resulted from the inhalation of this compound that its use was abandoned. (Marshall (1).) Marshall, himself, studied its action in 1898 and stated that it resembled chloroform but was even more toxic, more irritant to the mucous membranes, much more depressant to the circulatory and respiratory systems, and although anesthesia comes on more slowly than with chloroform it also passes away more slowly.

Little is found in the literature after this until in 1909 widespread attention was called to carbon tetrachlorid by the sudden death in a London hairdressing establishment of a young woman whose hair was being shampooed with this fluid. She collapsed in a few minutes and died almost immediately (2). Waller and Veley (3) undertook an investigation of the toxicity of carbon tetrachlorid, comparing its action with that of chloroform on isolated muscle. They found that the action of the former was slower; but, while the muscle would recover after chloroform poisoning, it would not after carbon tetrachlorid poisoning. They consider carbon tetrachlorid twice as toxic as chloroform. On the other hand, K. B. Lehmann's (4) animal experiments led him to assert that in large

doses it is less than one-half as poisonous as chloroform, in small doses about equally so. Rambousek (5) finds it only half as narcotic, but more irritant.

Lehmann says that workers using CCl_4 in dry cleaning may suffer from mental dullness and confusion and anesthesia, but that in many factories with good ventilation no trouble at all is experienced.* In one factory a man was sent into a reservoir which had been emptied of the cleansing fluid, but was full of vapors; he became maniacal so that it took four men to hold him; he was irrational for twenty-four hours and did not fully recover for eight days. Rabbits are susceptible to chronic poisoning and usually die on the third or fourth day from bronchitis and broncho-pneumonia after a daily exposure of eight hours to 8 to 10 mg. The odor is very strong when the air contains more than 3 to 5 mg. in a liter. As much as 5 to 10 mg. may be breathed for from six and a half to eight hours with no more serious effect than dullness, torpor, and sleepiness. With 20 mg. animals show increased drowsiness and headache; with 40 mg., narcosis, preceded by sneezing, itching of the eyelids, salivation, loss of equilibrium, muscle twitching; with 60 mg., helplessness, but not complete loss of consciousness, for seven hours. It requires 80 mg. to get deep narcosis, and 240 mg. will cause death at the end of two hours. Frois (6) states that 15 mg. per liter induces narcosis, headaches and vomiting in man.

One important point with regard to carbon tetrachlorid poisoning is brought out by Graham (7) who found that a more marked necrosis of the liver follows its administration to animals than is true of chloroform, and that the explanation lies in the fact that those bodies which yield the largest amount of HCl in their breakdown manifest the strongest tendencies to produce necrosis. Four molecules of HCl can be obtained from CCl_4 , only three from CCl_3 , and two from dichlormethane, CH_2Cl_2 , and the minimum fatal dose for rabbits is smallest for CCl_4 , next for chloroform, and largest for dichlormethane.

This breakdown in the body, with liberation of HCl , reminds one of the mode of poisoning when phosgene gas is inhaled; and in fact poisoning by carbon tetrachlorid under certain conditions is really poisoning by phosgene gas. According to the experiments made by Fieldner and Katz (8) of the Bureau of Mines, the use of carbon tetrachlorid fire extinguishers in mines or in other enclosures without abundant air supply, results in the production of vapors containing not only the ordinary products of combustion, carbon monoxid and carbon dioxid, but carbon tetrachlorid, hydrochloric acid,

* A recent report of the German Factory Inspectors states that a woman employed in a dry cleaning house was killed by fumes of carbon tetrachlorid which she inhaled when she leaned far into a fur-cleaning machine which was full of the liquid.

and phosgene. "Taking the maximum figures obtained as the most dangerous condition from the use of one quart of extinguisher on a fire in a 1000 cubic foot space and comparing the figures with the concentration of gases that can kill a man by exposure for thirty minutes, the following results are obtained:

Gas	Maximum concentration found in 1000 cu. ft. chamber, p.p.m.	Kills a man after 30 minutes' exposure, p.p.m.
CCl_4	6673	48000-63000(4.8-6.3%)
COCl_2	43	25
Cl_2	174	860 (kills dogs)
HCl	972	1000
SO_2	214	—
CO} .....	.51 (per cent)	.4 (per cent)

The maximum figures represent very dangerous atmospheres for a person exposed thirty minutes, and undoubtedly exposures of 5 or 10 minutes might produce effects decidedly unpleasant and lasting, not to say serious. The results confirm previous tests made with carbon tetrachlorid extinguishers on fires in small confined places and point anew to the danger of gassing should persons be unable to escape from the gases or should the gases not be removed by ventilation."

Two cases illustrating this danger occurred in the Portsmouth Navy Yard on January 10, 1919. The men, an electrical welder and his helper, were sent into a water ballast tank under the engine floor of a submarine. It was a compartment which could only be reached from the engine room floor through seven successive man-holes. The clothing of one of them caught fire by a spark from the electric torch and the other threw Pyrene fire extinguisher over the clothing to put it out. Both men were overcome by the fumes so that they could not save themselves and the only possible way to get them out was to cut a hole with oxy-acetylene torches through the outer hull of the vessel. They were burned by the hot metal from the acetylene torch used to cut through the hull but not severely enough to endanger life. They were taken to the Naval Hospital where they developed pneumonia and died, one on January 15th, the other on January 19th. The clinical notes of this latter case show that on the day of entrance there were râles over both lungs, respirations 30 per minute, temperature 101, pulse 120. The following day the temperature was 102, pulse 140, respirations 48. His condition improved during the next three days, but then dullness and fine râles with decreased breath sounds developed in the left lung and severe pain. The temperature rose to 104, the pulse

to 150, respirations 50—these being the last notes made before death. According to an industrial insurance man, six deaths are known to have occurred recently from the use of this form of fire extinguisher.

Chronic CCl_4 poisoning occurs sometimes in rubber works where this chemical is used as a solvent, especially in tire building; but the effects are distinctly less serious than those of carbon disulphid, and its substitution is an advantage. I have never found a case of very serious poisoning from this source although in three rubber factories I found men who complained that their health had begun to suffer from exposure to the fumes. Nausea; loss of appetite; loss of weight, irritation of the eyes, nose, and throat; and inflammation of the skin of hands and forearms, were the symptoms they described. I have also been told that men using CCl_4 in wiping joints to get rid of the grease, complain of nausea and headache. Von Jaksch (9) quotes Erben as saying that he had observed severe nervous disturbances in workmen who used a cement called "Dermantin," the solvent of which was carbon tetrachlorid, to line kettles.

In a series of cases of occupational poisoning from the use of a millinery cement described by E. B. Starr of the Ohio State Department of Health (see chapter on Benzene) the effect of this compound is discussed. The cement in question contained as solvent carbon tetrachlorid 66 per cent and 70 per cent, benzene 34 per cent and 30 per cent, with a trace of carbon disulphid. He quotes Lehmann to the effect that 3,980 parts per million of air, about 0.4 per cent, may be inhaled for about an hour without very serious effects. The vapors are heavy, even heavier than benzene, and since none of the cases of poisoning studied by Starr exhibited any soporific symptoms he believes that the trouble arising from the use of the cement should be attributed to the much more toxic benzene. It is worth noting that the girls complained more generally of burning in the throat and eyes than is usual in benzene workers.

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TETRACHLORETHANE

Tetrachlorethane, $C_2H_2Cl_4$, sometimes known in industry as acetylene tetrachlorid, is the best solvent for cellulose acetate, which, because it is non-inflammable, is used for purposes for which the inflammable cellulose nitrate, or celluloid, is not adapted. Thus it was the chief constituent of the coating or "dope" which was applied to battle planes, and it is now used to make non-inflammable moving-picture films. It is also employed in one process of artificial silk manufacture and as a constituent of certain lacquers.

Tetrachlorethane was one of the substances taken up by K. B. Lehmann (1) in his studies of toxic gases of industrial importance. As always, his experiments were for the purpose of determining the minimum amount of vapor which would produce intoxication, and he found that air containing no more than 0.001 to 0.002 per thousand parts could be breathed for a relatively long period, six to seven hours a day for eighteen days spaced over four weeks, with no more serious effect than loss of weight and drowsiness. If the fumes were stronger the effect was like that of chloroform but much more intense. Indeed, he found it the most toxic of all the chlorin derivatives of the hydrocarbons, being about four times as much so as chloroform and nine times as toxic as carbon tetrachlorid. Repeated exposures caused profound disturbances of metabolism, loss of weight, appearance of bile-coloring matter and albumin in the urine, sometimes hemoglobinuria, and evidence of destruction of the red cells of the circulating blood and of the formation of new cells with basophilic granulation. There was fatty infiltration and degeneration of the liver and minute hemorrhages into the mucous and serous tissues.

The first cases of industrial poisoning from tetrachlorethane occurred in Germany in an airplane plant in Johannisthal where eight men were employed in spraying a solution of cellulose acetate over the linen which covered the wings. Four of them developed a hematogenous jaundice and one died (Jungfer (2)). Later, in another factory, ten were poisoned and one died, and soon after Grimm (3) reported fifteen cases of this form of toxic jaundice. The solutions were sent to the Pharmacological Institute of the University of Berlin for analysis and experiment by Heffter and Joachimoglu and the active agent was found to be the tetrachlorethane, of which some specimens contained as much as 80 per cent. Animals exposed to the vapor developed a fatty degeneration of the liver more extreme than that produced by any known substance except phosphorus, and, as in phosphorus poisoning, it was associated with flabby yellow heart muscle and acute degeneration of the kidney epithelium. The effects also resembled delayed chloroform poisoning, but the hemolytic power is seven times that of chloroform.

This accident and the investigation which followed saved the Germans from serious trouble in airplane manufacture; for before the outbreak of the war orders had gone out to abandon the use of this solvent in airplane doping. In England the first case came to light in October, 1914, when a man died of acute jaundice after eleven weeks of work as a doper. (Wilcox (4).) Ten more cases were discovered by Legge in the same plant, developing after three to sixteen weeks' exposure. Then three women died of the same toxic jaundice. Wilcox's examination of the doping fluids gave exactly the same results as those of the Germans, but under the stress of wartime production it seemed at first impossible to give up this tried and efficient solvent and venture on some substitute. Many attempts were made to protect the workers by removal of fumes or abundant provision of fresh air and by diminishing the quantity of tetrachlorethane in the dope, but even as little as 10 per cent proved to be dangerous and cases of poisoning continued to appear, till finally in January, 1917, the Government announced that a satisfactory non-poisonous solvent had been found and tetrachlorethane would no longer be used. Seventy known cases of toxic jaundice with twelve deaths had been reported up to that time. (Legge (5).) Wilcox (4) says that the distinctive features of this poison are: slow insidious onset; a longer duration after onset than in acute yellow atrophy; absence of marked fever, such as is found in Weil's disease; acute infectious jaundice; absence of anemia, as is seen in arsenical poisoning; and a deeper jaundice than in delayed chloroform poisoning. Wilcox stated that, contrary to what was thought at first, it is not a hematogenous but a true biliary jaundice with the earliest changes appearing in the bile capillaries, and that there is no appreciable anemia nor are there changes in the red blood corpuscles.

The British experience was well known in this country before we entered the war and in consequence the battle-planes made over here were doped with a solution which did not contain tetrachlorethane.

Koelsch (6) of Bavaria published in 1915 a description of the milder forms of poisoning from this substance. He finds that the cases fall into two groups: the gastro-intestinal, with nausea, vomiting, cramp-like pains (two cases were diagnosed as lead colic), enlarged liver, and jaundice; and the nervous group, with headache, paresthesias, tremors of the hands, disordered reflexes, slight paralyses. He also noted drowsiness and an increased craving for food coincident with loss of weight.

A very valuable addition to our knowledge of tetrachlorethane is furnished by a careful study of sixty-eight persons employed in an artificial silk factory in work exposing them to tetrachlorethane fumes. Parmenter (7), Minot and Smith (8), of Boston, were able to follow the physical condition and blood findings of these indi-

viduals over a period of more than two years. None of these persons were seriously poisoned, but they presented a clearer picture of the early symptomatology of this form of industrial poisoning than can be obtained elsewhere from the literature. The earliest symptoms in a typical case consist in a sense of abnormal fatigue, the patient perspires freely, drowsiness comes on with loss of appetite, nausea, vomiting, constipation, and headache. The abnormal fatigue, general discontent and nervousness, inability to concentrate, loss of appetite, headache, and insomnia, serve as a warning that the worker should be removed from contact with the fumes. Even when the symptoms are very vague and indefinite a distinct and important change is found in the blood, consisting in a leucocytosis which depends on an increase of large mononuclear cells (probably endothelial cells) with a corresponding fall in polymorphonuclear cells and lymphocytes. Many of these large cells are broken and immature. A high count of large mononuclears, as much as 20 per cent, usually indicates poisoning, and a large number of broken cells seems to indicate rapid progression of the poisoning.

Severer symptoms consist of an increase of constipation, nausea and vomiting; and, in addition, gas in the stomach, generalized abdominal pain, dizziness, and very slight jaundice. Such disturbances usually appear gradually, rarely with sudden onset. With increasing jaundice there is evidence of cholemia which is associated with necrosis of the liver cells, much as in acute yellow atrophy. Besides jaundice the important physical signs which develop relatively late consist chiefly of a palpable and tender liver, general abdominal tenderness, pallor and loss of weight.

The symptoms do not always subside at once after removal from exposure, but sometimes increase for a few days and jaundice is likely to persist for weeks or months even if it is not severe.

The blood findings of the sixty-eight persons studied by Minot and Smith showed in addition to the changes in the whites already mentioned a slight but progressive anemia and a slight increase of platelets. The early and mild symptoms were very definitely connected with the changes in the white cells. And yet a certain amount of tolerance seemed to develop in some men who showed as much as 30 or 40 per cent of large mononuclear cells with no severe symptoms. In a later communication, Parmenter asserts that it is entirely feasible to use tetrachlorethane in industry provided proper precautions are taken to prevent escape of fumes so far as possible, and provided a system of medical supervision is installed so that by examination at stated intervals of the blood of individuals exposed to fumes, susceptible workers may be detected and serious poisoning warded off.

Tetrachlorethane is used in France for the manufacture of artificial pearls and according to Fiessinger and Wolf (9) two cases of

toxic jaundice from this source came under their observation. The first symptoms in these cases were fatigue, nausea, headache, constipation, vomiting, then, on the third and fourth days, jaundice. One of the men died and at autopsy it was shown that the liver is first and chiefly involved. Frois(10) reports three deaths which occurred recently among workmen engaged in this industry, which number may include the case just described. The dangerous process seems to be the coating of the pearls with a solution of fish scales in tetrachlorethane and then evaporating the solvent. This is not done in all establishments. Frois speaks also of the use of tetrachlorethane in the manufacture of varnishes in France, and of colors and lacquer; in the rubber industry; in the extraction of certain alkaloïds and oils; and in lithography and many other processes. Workers vary much in their susceptibility, but if one is affected even slightly he seems likely to have a severe attack if he is again exposed to the vapors.

Another French article, by Lèri and Breitel (11), describes two cases of polyneuritis of long standing, which they attribute to tetrachlorethane, and the predominating symptom of which was paralysis of the interosseous muscles of the hands and feet.

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OTHER CHLOR COMPOUNDS

Other chlor compounds of this series are used in industry, but as yet only to a slight extent. Methyl chlorid, or chlormethyl or monochlormethane (CH_3Cl), was the cause of two cases of narcotic poisoning in Germany. Kobert (1) says it is only one-fourth as toxic as chloroform, and Rambousek (2) finds it irritating, but only slightly narcotic. The two cases were reported by Gerbis (3) in 1914. Both were machinists employed in cleaning apparatus

through which methyl chlorid was sent. They suffered from extreme somnolence, sometimes sleeping 24 hours at a time, and both had very decided diminution of vision which, however, cleared up later on. The oldest, a man of 63, had an attack of delirium followed by prolonged sleep.

Trichlorethylene, C_2HCl_3 , was used extensively by the Germans during the war as a substitute for benzene, alcohol, and other fat solvents, and in 1916 Plessner (4) published an account of four cases of poisoning in a munitions plant in which it was kept in open cans. The men had worked with it only from half a day to one day. While at work, they suffered from smarting of the eyes and burning of the skin of the hands so that they had to run and wash them off. After reaching home, complete dumbness of the mouth, cheek, and nose, including mucous membrane and the skin of the face, developed. It was a sensory paralysis of the three branches of the trigeminus on both sides, but all parts of the head supplied by the spinal nerve escaped, the edges between the two areas being sharply outlined, and the cornea was absolutely anesthetic. This occurred in March and when Plessner wrote his report in November anesthesia was still complete, but there was no keratitis neuro-paralytica. The front part of the tongue had lost the taste for sweet, could detect salt, but was normal for bitter taste; the sense of smell was completely gone. Only one man had trophic disturbances, the loss of 14 teeth, and nutritive disturbance of the optic nerve. The second man had, at the time of writing, edematous swelling of the papilla, and the third had no visible change in the eye ground but changes in color sense, colors shifting as he looked at them. This, Plessner holds, came from injury to the nervi nervorum which come from the trigeminus. There was no involvement of the motor fibers of the trigeminus.

The latest report of the German Factory Inspection Department states that the chlorin derivatives of the fatty series are being tested by Lehmann of the Hygienic Institute of Würzburg, and trichlorethylene has shown itself to be less poisonous to animals than carbon tetrachlorid, and only one-fourth as poisonous as chloroform. However, it is not improbable that trichlorethylene, if used continually, may have an effect on human beings which is different from that observed in animal experiments. Various reports from industrial establishments show that troublesome symptoms have occurred from the use of this compound. For instance, in a dry cleaning establishment symptoms like those of chloroform poisoning have occurred, and in a rubber factory where it is used as a substitute for benzin for making rubber cement, two workmen lost consciousness. In another factory a woman showed symptoms of chronic poisoning, continual headache and mental dullness, and later insomnia and excitability, so that she was obliged to give up work.

This factory also was using trichlorethylene as a substitute for benzin and there was much more complaint of its effects than of those of the latter.

Trichlorethylene has lately been introduced into American rubber manufacture as a substitute for carbon tetrachlorid in preparing brake linings. A death from the fumes of this compound occurred early in 1923 in a New Jersey factory after an intermittent exposure for about a day and a half. Apparently the workman who died was trying to install some rods in a tank which had contained trichlorethylene and which still contained some "sludge." An attempt was made to blow out the tank with compressed air, but partly on account of the density of the vapor and partly on account of the sludge on the bottom of the tank, the effort seems to have been unsuccessful. The man was said to have been given a mask of some kind. He worked on Friday and again on Saturday morning and his fellow workmen reported that when he came out of the tank he seemed dazed and "dopey." They left work at noon, and an hour and a half later a watchman found him unconscious in the tank. He never recovered consciousness, although artificial respiration was practiced first by the Schaeffer method and later by the use of a pulmotor.

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METHYL BROMID

This is a compound which has a very marked and unique action on the human organism, and although it is of little if any importance in American industry, it is worth a brief description because it may very possibly be one of a group of compounds which will be found to have a similar physiological action. It is produced in the chemical industry, to be used for the preparation of methyl compounds for anilin dyes and for the preparation of antipyrin. Eleven cases of poisoning had been reported in the literature up to May, 1923, from Germany, Switzerland and France.

According to Röhrer (1), who reviews eight cases in the literature, and adds one of his own, the remarkable features of methyl bromid poisoning are: the long latency of a compound which is rapidly absorbed, and the fact that it disappears so quickly from organs and fluids that it has never been detected at autopsy, although it

produces a profound and more or less permanent damage to the nervous system. Röhrer's patient was a foreman in a chemical factory who twice in one day carried out some repair work on the methyl bromid apparatus. Nothing unusual was noticed in his condition that day except that he was unusually silent in the evening and appeared very weary. The following afternoon about three o'clock he was suddenly taken with violent jerking of the left arm; he soon lost consciousness and was taken in this condition to the hospital. When Röhrer saw him, he was in a condition of coma with deep inspirations, foam on the lips, pupils widely dilated; and convulsive attacks, affecting especially the muscles of the arms and of the jaws, succeeded each other with constantly shorter intervals until the condition became continuous. The blood flowed readily, was blackish in color but coagulated normally. The differential count of white cells showed 40 per cent mononuclears, but there was no abnormality of the red cells. The urine contained albumin but no sugar, acetone or acetic acid. Death came on about an hour after the onset of the attack. No bromin or bromin compounds were found in organs or fluids. It is impossible to say whether the effect on the nervous system takes place primarily in the ganglion cells or whether it is in the ductless glands, causing functional disturbance in the nervous system, or whether there is a general disturbance of metabolism which results in an accumulation of products capable of causing this catastrophic effect. Röhrer is reminded, by the sudden explosion of symptoms, of fatal anaphylactic shock.

The cases described by Goldschmid and Kuhn (2) were caused by the explosion of a cylinder containing 178 kilograms of methyl bromid. In all these the latency of the poison was a marked feature, for the symptoms did not develop till an interval of several hours for the shortest, up to two or three days for the longest interval. For instance, case No. 5 went into the room where the accident had occurred but which had been thoroughly aired and all leaks repaired and no one allowed in until two weeks had passed. He worked with no apparent discomfort for two days, went home, and later on was found in the street in a dying condition, with clonic convulsions and widely dilated pupils. He died on the way to the hospital. No. 6 had practically the same history after the same slight exposure. The autopsies on these men showed acute purulent bronchitis, inflammation and edema of the lungs, dark red fluid blood, slight fatty degeneration of the kidney epithelium, and a very marked acute degeneration of the ganglion cells of the cortex of the brain. The authors note that all the men who were treated in the hospital appeared stupid, as if hardly conscious, and for a long time they were depressed and melancholy. Seven months later they were apparently nervous, although capable of work. They had

tremors of hands and outstretched tongue and a neurasthenic condition.

This long continued neurotic condition is noted by Jaquet (3) in his first case, and by Bing (4) in his first case. Floret (5) describes three cases in one of which there was nausea, double vision, staggering gait, and after five days an attack of frenzy followed by coma and then by delirium with hallucinations, epileptiform attacks and prostration, followed by a prolonged period of mental apathy and languor and apparent muscular weakness.

Löffler and Rüttimeyer (6), failing to find any bromin or bromin compounds at autopsy on a case of typical poisoning from methyl bromid, exposed guinea-pigs to the fumes, and found that, if the animal were killed immediately after exposure, the substance could be demonstrated in fluids and organs, but that if it lived for 30 to 70 minutes after removal from the fumes it was almost, if not quite, impossible to detect methyl bromid in the body.

The last cases of industrial poisoning from methyl bromid reported in the literature are Cade and Mazel's (7), from a French chemical factory. In the first case, as in that of Löffler and Rüttimeyer, the man was exposed several times to the fumes of methyl bromid and at last succumbed to an exposure rather greater than usual. A leak occurred which he tried to stop with cotton an hour before he left the works. Sixteen hours after the inhalation of fumes he had diplopia with indistinct vision, his fingers and legs became useless, and he was unable to tell his name or to write it. He had violent pains in the legs and marked motor incoördination. In a second case the man, aged 59, had been engaged at times for 32 years in the manufacture of antipyrin and had had four attacks of mild methyl bromid poisoning with complete recovery in the intervals.

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CHAPTER 33

BENZENE

BENZENE, or benzol, as it is usually called, is one of the most important of the industrial poisons, but its use in industry is comparatively recent, and therefore the literature concerning industrial poisoning by coal-tar benzene and its homologues, toluene and xylene, is not very full; indeed most of it has appeared too recently to be incorporated in the text-books. It seems wise, therefore, to handle this subject as completely as possible; for there is every prospect that the use of coal-tar distillates will continue to increase in the near future, and it is of the greatest importance that the dangers attending them should be clearly understood.

Coal-tar benzol is properly called benzene and is represented by the formula C_6H_6 . Unfortunately this term is likely to be confused with petroleum benzin, but it is the one insisted upon by the chemists. Toluene (toluol) is methyl-benzene with the formula $C_6H_5CH_3$, and xylene (xylol) is dimethylbenzene, $C_6H_4(CH_3)_2$. These bodies are obtained as by-products in coking coal, and in the production of illuminating gas. They are collected in heavy oils, and distilled off.

Pure benzene distills at 80° to 81° C. It is a very volatile colorless fluid with a pleasant odor which is not locally irritating and which arouses no suspicion of danger. The vapors are three times as heavy as air. Toluene distills at 110° C. and xylene at 137° to 143° .*

Besides pure benzene and toluene and xylene, there are several kinds of commercial benzenes, which contain toluene, xylene, thiophene, and rarely traces of carbon disulphid.

The usual commercial products are:

PURE BENZENE—A clear colorless liquid of a characteristic odor. B.P. 79.7° C.

NINETY-PER CENT BENZENE—So called because in the distillation 90 per cent distills over at a temperature of less than 100° C. It is composed of 80 to 85 per cent benzene, 13 to 15 per cent toluene, 2 to 3 per cent xylene, and sometimes contains as impurities traces of olefins, paraffins, sulphuretted hydrogen and other bodies.

FIFTY-PER CENT BENZENE—This substance contains 50 per cent of constituents which distill below 100° C., and 90 per cent below 120° C.; it is a very mixed product, with only 40 to 50 per cent. benzene.

* Bloxam, C. G., *Chemistry, Inorganic and Organic*, Phila., 1923, p. 537.

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SOLVENT NAPHTHA—This material is called solvent naphtha because it is used extensively (especially in England) for dissolving rubber. It is relatively free from benzene, and consists largely of xylene.

In Germany commercial benzene, as used in the rubber trade especially, may contain a large proportion (from 16 to 60 per cent) of carbon disulphid. Thiophene is of no importance toxicologically.

Uses.—Benzene is used on a large scale in solvent extraction work, extracting oil and greases, but this is done in hermetically sealed apparatus, the benzene being removed from the products before they are taken out so that the danger, as in benzene production, is only the risk of some accident to the machinery. In French dry cleaning, benzene was used for a while just after the war, but the increased fire risk has led to its abandonment except in a few cases.

At present, benzene is used in every branch of rubber manufacture, not of course in all departments of every rubber works, but in some department in practically every individual plant. It is a much better solvent for gums, resins, and fats than is any petroleum derivative and it dries faster than high-test gasoline. It is used for cement in shoe factories and in millinery manufacture,* in the making of fabrikoid, artificial leather, and linoleum, in coating leather for upholstery and for automobile tops, and as a constituent of shellacs, varnishes, gilding and bronzing fluids, varnish and paint removers, and quick-drying paints for interior work.† Enormous quantities of benzene rubber mixture are used in the making of so-called sanitary food cans. In the manufacture of pharmaceutical supplies, benzene is used to crystallize out coal-tar drugs. It is the starting point of many important intermediates in dye manufacture, such as anilin, and is also the starting point of synthetic carbolic acid and of the important explosive, picric acid. Copper and zinc are cleaned with benzene in preparation for galvanoplasting, and photoengravers use it to dissolve rubber films. It is also used in the manufacture of kodak and moving picture films.

The largest commercial users of benzene at present, aside from the purveyors of motor car gasoline, are manufacturers of the following: rubber cement, rubber tires and shoes; brake linings, particularly for automobile brakes; artificial leather and fabrikoid; lacquers; cement for sanitary food cans; paint and varnish removers. All of these require the use of benzene in more or less open vessels or vessels which have to be opened from time to time.

The National Safety Council undertook to study benzene poisoning in industry during the year 1923 by sending out questionnaires

* The Ohio State Department of Health found in one millinery cement 49.5 per cent by volume, and in another no less than 92 per cent.

† Some of the newer quick-drying "flat coat" paints contain benzene in appreciable quantities. For instance, in one the liquid medium is 10 per cent benzene and the directions call for the addition of benzene if the paint is too thick.

to the producers and users of this compound, obtaining information from 67 firms. Thirty of these firms employed less than five in processes exposing them to benzene; four employed a hundred or over, the largest being a rubber factory where 1080 were so employed. Of the firms employing ten or more people in benzene work, eight were rubber factories, five were chemical works, four were paint and varnish makers, three were gas plants recovering benzene as a by-product, one was making celluloid and artificial leather, one japanned goods, and one was a can factory.

The substitution of benzene for petroleum distillate in motor car fuel leads to a change in the composition of the exhaust gases and undoubtedly adds to the danger from these gases in garage work. Yandell Henderson (1) and his colleagues have compared the amounts of CO found in the blood of dogs dying from exposure to various CO-containing gases and found that death occurred at a lower CO saturation when coal-tar distillate was burned than when gasoline was, and to a slighter degree this is true where illuminating gas is used. When pure CO was used, the blood at death contained 84 per cent CO; after illuminating gas poisoning, only 70 per cent CO was found in the blood; after death from gas from a motor car using gasoline, 83 per cent CO was found in the blood; but after death from gas from a car using coal distillate, only 62 per cent was found. The composition of this distillate was as follows: benzene, 69 per cent; toluene, 15.5 per cent; solvent naphtha, 13.5 per cent; heavy naphtha, 2 per cent.

The symptoms of illuminating gas poisoning differ from those of pure CO poisoning; for there is more respiratory excitement and quicker collapse, and there is nausea and vomiting. Apparently the action of gasoline exhaust gas depends entirely upon the CO that is present, but the exhaust gas from coal distillate causes symptoms resembling illuminating gas poisoning and the difference is attributed to the presence in both of these gases of benzene vapor. Kobert (2) also says that the greater toxicity of illuminating gas as compared with pure CO is to be explained by the presence of benzene in the former, and Staehelin's experiments prove the same. He was using CO on frogs; but, running short of the pure gas, he undertook to substitute illuminating gas, whereupon the frogs developed convulsions, as they had under CO. Staehelin (3) found that benzene vapor in the gas accounted for this difference. (See Haggard's experiments with neuroblasts, p. 396.)

There has been much controversy as to which is most toxic, pure benzene or crude benzene, or the mixtures of benzene and its homologues commonly used in industry. Lewin (4), testing vapor on animals, found impure benzene more toxic than the pure. Chassevent and Garnier (5) say the same. Lehmann (6) tested the pure, the commercial, and the crude, and found them not very

different, the crude being slightly the most toxic; but the individual variations in the susceptibility of animals rendered the conclusions dubious. Lehmann says that the early symptoms come on most quickly with benzene; but narcosis, most quickly with toluene. On the other hand, Kobert (2) says toluene is much less toxic than benzene, but more irritating to the mucous membrane, though with less convulsive effect, for it is changed to hippuric acid in warm-blooded animals. Rambousek (7) found pure benzene the most toxic. Toluene, xylene, and solvent naphtha (which, he says, is a mixture of the higher benzenes, cumene, pseudocumene, and mesitylene cumene) all cause less convulsive effect and slower narcosis. Xylene is less poisonous than toluene. The recovery from toluene poisoning, however, is less rapid than from benzene poisoning. Agasse-Lafont and Heim (8) also insist that pure benzene is more toxic than crude. Hektoen and Brown (9) found far less striking and characteristic changes in chronic toluene poisoning than in chronic benzene poisoning. (See later.) Just recently Pugliese (10), investigating the cause of several deaths from benzene poisoning in a raincoat factory in Milan, tested the comparative toxicity of several varieties of this solvent which were used in the factory, and found that pure C_6H_6 acted most rapidly and intensely on animals, while the impurest and most ill-smelling sample was the least toxic. He found toluene less poisonous than benzene, but the vapors more irritating to mucous membranes, causing watering of the eyes, sneezing, and coughing.*

Effect on Animals.—Benzene has a pronounced action on the central nervous system, narcotizing, and lowering the body temperature. Animal experiments reveal a great difference in susceptibility, not only between different species but between different individuals in the same species. The vapors of benzene are toxic for animals when present in the proportion of 0.015 g. to 0.016 g. per liter of air (Rambousek). At this dilution the animal begins to show jerking of the leg muscles after 50 minutes. This symptom comes on immediately at a concentration of 0.056 g. per liter of air, convulsions develop in eight minutes, unconsciousness in ten. Dogs are more susceptible than rabbits and die after 20 minutes' exposure to 0.042 g. per liter of air. No after-effects are noted in animals surviving the experiment, and in those that die, nothing is found but moderate hyperemia of the brain, lungs, and mesenteric vessels.

Lehmann, experimenting with cats, found a decided variation of susceptibility in individuals, but all of them showed signs of irritation of the mucous membrane, muscular twitchings, and a fall of body temperature. In large doses there were convulsions;

* Cases of industrial poisoning from toluene are rare. British factory inspectors report a death from toluene fumes in a man who entered without a gas mask a tank which had held toluene and some ammoniacal fluid.

narcosis; very deep respirations, first quick then slow; quickened pulse, and death from respiratory paralysis. A narcotic effect begins in cats after two hours' exposure to 0.02 g. per liter of air, and narcosis is complete in six hours. With 0.06 g. the periods are fifteen minutes and one hour, respectively. In man 0.015 g. per liter of air produces listlessness and confusion after half an hour, and exposure to 0.02 to 0.03 gm. (or from 2 to 3 parts per 100,000 parts of air), for a few hours may cause loss of consciousness.

Lehmann found the symptoms in animals very uniform in character, although varying in degree. First comes restlessness and excitement, partly from irritation of the nose and throat, especially with crude benzene, toluene, or xylene. Next, and fairly quickly, come symptoms of central irritation, dizziness, staggering, unco-ordinated movements, and twitchings of the muscles lasting from half an hour to many hours and affecting single muscles or groups of muscles or whole limbs. The movements are clonic, sometimes tonic, but there is no tetanus. This condition makes observations on respiration and heart difficult; but apparently the former is first quickened then slowed, and the heart is rapid. At the end of the experiment a decided fall in temperature is always found, and this may be the cause of the twitching. The animals recover completely with no after effects, or else they die suddenly from primary respiratory or heart paralysis. Nothing typical is found at autopsy except that the blood remains fluid for a long time.

Acute Industrial Poisoning.—The earliest cases of acute poisoning were reported from Germany. At the Brussels International Congress of Industrial Hygiene in 1910, Rambousek summarized the histories of 22 cases* which he had gathered from the literature of that time. All these were acute cases and occurred in the following ways. Case 1 was distilling benzene, and forgot to turn on the cool water to condense the vapor. Case 2 was found dead before the building the next morning after he had let 900 liters of benzene overflow from a vat. Cases 3, 4, and 5 were poisoned in a benzene vat in a rubber factory; the two latter entered it to rescue the first. Cases 6 and 7 were exposed to benzene gas in a coke by-products plant. Cases 8, 9, and 10 were exposed to a mixture of benzene, hydrogen sulphid, and cyanogen compounds. Case 11 was cleaning apparatus in a benzene plant. Cases 12, 13, and 14 were reported by Lewin in 1907. They occurred in connection with work in a benzene extraction kettle. The next five were cleaning vats for the transport of benzene. Case 20 occurred in a rubber factory. Of the last two, one was making antipyrin, the other was painting an iron tank with asphalt dissolved in benzene. Eighteen of these cases were fatal.

* I have omitted Santesson's nine cases, which were chronic.

The literature of other European countries and of the United States have added many cases to this list during the thirteen years that have elapsed since then. These are typical histories selected from the mass of available material.

Lewin, in 1907, reported a case of fatal poisoning in a workman who had tried to rescue a man overcome with benzene fumes. A benzene kettle had stood empty for 22 hours, when it was washed out three times with cold water and twice with steam, and was allowed to stand all night filled with cold water. The man who was sent in to make repairs took with him a pipe through which was blowing a strong current of compressed air. Nevertheless, he fainted and fell to the bottom of the kettle. Several men tried to get him out, but all grew dizzy and confused and had to give up, until an engineer, with a diver's helmet succeeded in dragging him out. He was revived, but one of the men who tried to rescue him died ten minutes after climbing out of the kettle.

The German factory inspection report for 1913 contains an account of a similar case. Here, also, the tank was supposedly thoroughly cleaned; for it was boiled out three times, but the workman who went in lost consciousness; and although the two men who had been set to watch him dragged him out promptly he never revived. Beisele's (11) case was that of a man who died after only four minutes' exposure from dipping benzene out of a bowl.

The earliest instances of acute benzene poisoning in American industry were reported from establishments producing and using benzene for the manufacture of anilin and of explosives. By 1916, fourteen acute cases had been reported, seven of them fatal. The first two were in steamfitters employed in repairing pipes inside a benzene still where the manhole through which they entered was just large enough to allow them to crawl through. As usual, the still had been not only emptied but washed out, and it was supposed to be free from dangerous quantities of benzene; but soon after the men went in one of them became excited and irrational, singing and shouting. It was realized that he must be got out as quickly as possible; but this was a difficult thing to do through a narrow manhole, especially since he was irrational enough to resist. It took about ten minutes to get him out, and during much of that time the manhole was completely closed by his body. The second workman, who had been helping to lift him out, was then found to be lying unconscious on the floor of the still. Even more difficulty was encountered in removing him, for he was quite helpless, and when he was at last brought into the open air, which was after about twenty minutes, he was found to be dead.

The third and fourth cases had almost the same history. They, too, were in men who were working inside a still which was supposed to be free from benzene. They began to suffer from the effects,

were dragged out in a state of coma, given vigorous treatment by the administration of oxygen and stimulants, but one died, and curiously enough he was the one who had had the shorter exposure. Two other fatal cases were caused by repair work in a benzene still. The fifth death was caused by a leak from a still, and the sixth and seventh were in men working in the sulphonating department of a phenol plant where benzene was sulphonated and where fumes escaped from the supply pump, the sulphonating kettle, and the liming vat.

In many cases it has been impossible to say whether or not death was instantaneous because the victim was not found till some time after. Sury-Bienz's (12) patient died in a very few minutes, as did Beinbauer's (13); but Heffter's (14) lived several hours. He was an assistant manager, and, accompanied by two helpers, he went into a cellar to open a benzene pipe which was stopped up. He started the flow, but could not stop it, and benzene splashed over his clothes. The helpers complained of feeling sick and he went upstairs with them, got two other men and went back to the cellar for half an hour. When he came up he fell in a faint at the top of the stairs, and although oxygen was administered for three hours he never revived.

I have the history of a case of acute benzene poisoning from a Pennsylvania phenol plant in which oxygen was given for more than two hours without saving the man. It is noteworthy that exertion increases the severity of the poisoning, or at least that seems the only way to explain the considerable number of accidents in which it is the rescuer who dies while the original victim, though sometimes exposed longer, survives. Of course individual susceptibility plays a great part. Lehmann (6) believes that this is the underlying cause of sudden death from benzene poisoning in industry. One of the many illustrative instances in the literature is a case described by Lewin. A workman had gone into a benzene extraction kettle and had fainted. His helper climbed part way in to rescue him, felt himself growing dizzy and confused, and backed out at once, but died in ten minutes, while the first man, who lay unconscious in the tank for several minutes before he could be removed, was saved.

That such an anomaly should give rise to controversy in compensation cases is inevitable. In one of the great steel works of Pennsylvania, two workmen were sent into a benzene tank to change the coils after the tank had been thoroughly blown out with steam. One of them was quite unaffected by the benzene vapor, while the other died from its effects. The statement of the company doctor that there was something in the man's constitution which caused his death is true in the same sense in which it is true that something in a man's constitution causes him to succumb to typhoid infection

if he drinks polluted water while another man, drinking the same water, remains quite well.

As a usual thing men recover completely, if they recover at all, from such accidents; but there are a few instances of sequelæ recorded. Kobert described the case of a man who was painting the inside of a reservoir with bitumen and crude benzene and who suffered an attack similar to alcoholic intoxication from which he recovered; but later, without further exposure, developed pleurisy and apical catarrh of the lung, and was never restored to complete health. One of Lewin's cases, with relatively slight symptoms, had persistent after-effects. This man had an acute attack of dizziness, a drunken feeling, pressure in the head, dyspnea, oppression of the heart; and when these passed over, a blowing heart murmur, yellow pallor, and general nervous exhaustion. A rather unusual history is given in the report of the British factory inspectors for 1918. The man was employed on the night shift in a benzene distillery and on a certain night the volume of vapor was greater than the condenser could deal with, some of it escaped, and he was overcome. He was revived with oxygen and the next night returned to work; but although at that time the still was working well he was again overcome and this time he died without regaining consciousness.*

Irritation of the skin, or inflammation with swelling and itching, is noted in some cases of acute benzene poisoning (Simonin (15)).

A strange story, possible only in Czarist Russia, was told by Dworetzky (16) in the spring of 1914. It deals with an epidemic of mysterious illness in the factory population of St. Petersburg, beginning in a large rubber works and extending to chocolate and tobacco factories. It was the cause of widespread excitement, strikes, lockouts, riots, a heated controversy between two schools of doctors, interpellations in the Duma, and ended in the complete suppression of all discussion and inquiry by the chief of police.

* The following regulations have been formulated by the British Factory Inspection Department to govern work in tanks or other receptacles which have contained benzene or toluene: 1. The period of airing the tank must last six days. 2. The tank must be filled with water and then steam introduced till the water boils. The steam pipe must reach to the bottom of the tank and either by stirring or in some other way the sludge must be mixed with water. 3. If a tank has remained empty for some time it must be filled with water and emptied before anyone goes into it. 4. Entering a tank and working inside must be permitted only to men wearing a helmet or mask which is connected by a rubber pipe to fresh air or provided with a breathing apparatus which will allow the man to breathe normal air or a mixture of oxygen and air. 5. Every man who enters a tank must wear a safety belt with a rope attached and the other end of the rope must be held by a man outside. 6. An oxygen flask with face mask and proper connections must always be available.

An excellent precaution is used by the United States Steel Company in their plant at Gary, Indiana. After emptying, washing out, and steaming out the tank, they lower into it a cage of white mice, and if the mice are overcome by the vapors the process of flooding and steaming is repeated until the little animals can be lowered into the tank without showing any effect.

The starting point was the rubber glove department of a great rubber factory where hundreds of women were employed in cementing gloves. The solvent for the cement had recently been changed from an ill-smelling, colored fluid to a colorless one with a pleasanter odor; and following this change an acute illness developed among these women, consisting of headache, dizziness, excitement, in many cases fainting or epileptoid convulsions, and involving, in four days' time, no less than 231 of them. Physicians were divided between those who maintained that there was a toxic substance in the cement, and those who held that it was pure hysteria, the latter group being led by von Bechterew. Color was lent to the hysteria theory by the enormous excitement which the discussion had aroused in the working population who believed there was a conspiracy among the employers to poison them, and by an outbreak of similar symptoms among the women in the tobacco and the chocolate factories. The real nature of the trouble could not be known; for before any investigation could be made, the manufacturers declared a lockout until the workers would promise to be quiet, and the police forbade any inquiry into the nature of the trouble or any discussion of the occurrences, maintaining that it was all the work of agitators and revolutionists.*

Pathology of Acute Benzene Poisoning.—The earliest autopsy record I have found is that published by Sury-Bienz in 1888. He found conspicuous bright red spots on the body; the blood fluid and dark red; small hemorrhages in the pleura and intestinal mucosa; general venous congestion and reddened lining of the air passages which contained blood and mucus. Beinhauer (13), in 1896, described the findings in the body of a man dying of acute poisoning after exposure to fumes in a benzene extraction apparatus. The blood in heart and vessels was fluid, the veins of the abdomen engorged, there was hemorrhage in the gastric mucosa, and bloody foam in the air passages. Beinhauer says that the blood was lake red, weakly acid, and there was evidence of destruction of the red cells; but this is contrary to the great weight of evidence. (See Kobert, on absence of blood destruction in experimental animals, also Lehmann.) There was a curious aromatic odor from the body, but no benzene odor in the blood, and no benzene could be demonstrated chemically.

Heffter, in 1910, reviewed the 21 cases of acute benzene poisoning which had been reported in Germany up to that date. He says that the most characteristic change noted in animals is found also

* While in Moscow in October, 1924, I made inquiries about this occurrence and was told that similar trouble had developed among the women employed in rubber factories in Riga and in Moscow at about the same time as in St. Petersburg. All these factories were using a solvent from Baku which was supposed to be petroleum naphtha. After the excitement had died down, a quiet investigation was permitted and the fact established that the toxic substance was benzene.

in men. The blood remains fluid a long time, dark red; but there is no evidence of destruction of the red corpuscles. Hemorrhages, usually punctate, are found in lungs, pancreas, gastric and intestinal mucous membranes. The abdominal organs show unusual congestion, and there is bloody mucus in the air passages. There are numerous cadaveric bright red spots, there is no odor of benzene and it cannot be detected chemically.

Buchman's (17) case was in a man using benzene as crystallizing material in the production of coal-tar drugs, antipyrin and pyramidon. He was found dead on the floor near a leaking apparatus. There were many wine-red spots on the skin, pronounced hyperemia of the internal organs, and small hemorrhages in the pancreas.

Two of the men who died of benzene poisoning in our munition industry during the war came to autopsy, and I am indebted to Dr. H. S. Martland of New Jersey for the notes of his findings which may be condensed as follows:

Case 1. Cyanosis of the mucous membranes and finger tips: cyanosis of the liver, spleen and kidneys: dilatation of the right heart which was filled with dark fluid blood: pleural ecchymoses and small areas of acute interstitial emphysema in the lungs.

Case 2. Cyanosis of mouth, of lips, and of finger tips; small amount of frothy fluid escaping from the mouth; cyanosis of brain, heart, liver, and kidneys; petechial hemorrhages in pleura and pericardium; reddened and irritated bronchi. On section of the lungs a decided odor of benzene was given off. There was an abnormal quantity of phenol in the urine, but no benzene.

The same statement as to the presence of phenol bodies in the urine is made by Heffter and by Beisele, who failed to find blood or albumin or hematoporphyrin; and by Simonin who found in addition urobilin, diminished urea, and diminished chlorids. The phenol is excreted as conjugated sulphuric or glyeauronic acid, but this change is fairly slow and does not occur in rapidly fatal cases (Heffter (14)).

Chronic Benzene Poisoning.—The earliest and probably the most famous cases of chronic benzene poisoning in the literature are Santesson's (18), from a velocipede tire factory in Upsala. These were twelve young women, 15 to 20 years of age, employed in the tire department and recently they had been working overtime. All of them developed more or less severe hemorrhages, nine of them having purpuric spots on the skin, one, epistaxis and hemorrhage from the gums and vomiting of blood, one, uterine hemorrhage, and another, prolonged menstruation. Four of them died after exposure of three weeks to four months. A typical history is that of a girl of 19 who had worked for three to four months and had suffered from dizziness and excitement followed by drowsiness. She lost weight and color and left the factory; but instead of recover-

ing she grew worse, ecchymoses appeared on the skin, the number of red corpuscles fell to 3,764,000 with 80 per cent hemoglobin, there were almost no leucocytes to be seen; she grew gradually weaker, and died after a period of feverishness. Another girl, also 19 years old, who had tuberculosis, worked for eleven to twelve weeks, ten to twelve hours a day, when she was discharged. Three weeks later she had profuse menstrual hemorrhage, purpuric spots appeared over the skin, she had vomiting and dyspnea, and profound anemia. The red cell count fell to 600,000 with hemoglobin 20 per cent just before death.

This same year, 1897, Lenoir and Claude (19) reported a case of purpura hemorrhagica in a man who had been employed for several years in a dye house where he was exposed every day to fumes of benzene. He had bleeding from nose and gums, purpuric spots on the skin, increasing cachexia, and then died suddenly. At autopsy they found bloody effusion into the pleural cavity, hemorrhages into the mucosa of stomach and intestines and under the endocardium, and myocardial infarcts.

It remained for Selling (20) in 1910 to declare that the most characteristic feature of chronic benzene poisoning is not the hemorrhages or the anemia but the profound leucopenia, and that the lesions are essentially those of aplastic anemia with destruction of hemoplastic tissues. Selling's patients, three in number, were employed in the coating room of a tin can works where a sealing mixture was used consisting of pure rubber and resin, dissolved in commercial benzene. Twenty-three persons were employed in this department, 5 men machinists, 4 girl inspectors, and 14 girls at the coating machines. These last were between 14 and 16 years of age, and they suffered most severely. Not only were the cans coated here but they were also dried, and ten gallons of benzene a day evaporated in that room. The windows were open, but it was very hot midsummer weather.

Case 1 entered the hospital in fairly good condition, complaining only of "spots on the body and dizziness." She had worked about four months, and a month before she came to the hospital she had noticed blue spots on arms and legs; then, shortly afterwards, she began to have bleeding from the gums, nose and throat, one nose-bleed lasting two days. A few days before admission there was a severe hemorrhage from the throat, controlled only with difficulty by local applications. For a week she had been in bed because of weakness and dizziness. Examination showed only extreme pallor, purpuric spots, bleeding gums, a hemic murmur over the heart. Examination of the fundi showed a number of retinal hemorrhages.

For the first few days the patient was in fair condition, but on the sixth day she suddenly developed signs of profound toxemia and fell into a stupor, her pulse small and weak. Transfusion of blood

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was followed by decided improvement in symptoms, but not in the blood count, and a relapse occurred two days later from which she did not rally, dying on June 6th, the ninth day after admission. Her temperature ranged from 99.8 to 104.6 F., her pulse from 108 to 165. There was no evidence of hemolysis in the urine nor did jaundice appear.

The blood smear showed the red cells smaller and paler than normal, but no poikilocytosis and no extremely large or small forms. The counts were as follows:

	Reds	Whites	Hemoglobin
June 28th, on entrance.....		1280	28% (Sahli)
July 1st	1,090,000	480	11%
July 3d	800,000	480	
July 4th	640,000	600	8%

Platelets were practically absent; blood clotting was delayed and incomplete. A differential count showed: polymorphonuclears 43 per cent, lymphocytes 41 per cent, large mononuclears 14 per cent, unclassified 2 per cent. Only one myeloblast was seen, but no normoblasts.

Case 2 was also 14 years old, had worked five months, and complained of illness for only one week. Her history, physical examination, and the course of the disease were very similar to those of Case 1. Her blood counts fell from 2,100,000 reds to 1,150,000; from 560 whites to 140; and the hemoglobin fell from 37 per cent to 15 per cent. The lymphocytes constituted 71 per cent of the whites, with 10 per cent large mononuclears and only 16 per cent polymorphonuclears. A platelet count (Pratt's method) yielded only 2,500 per cubic centimeter, and the blood after standing 48 hours in a tube showed no expression of serum.

Case 3, a girl of 14 years, had worked for about three months and had suffered for two months from anorexia, abdominal pain, vomiting and headache, and one or two fainting spells. She had a much slighter purpuric eruption than the others and her blood count was 4,900,000 reds, 4,400 whites, hemoglobin 54 per cent, platelets 104,000. Clotting of blood was incomplete, as in the other cases. She was discharged after six days.

The autopsy of Selling's first case, made by W. G. MacCallum, showed: hemorrhages in skin, viscera and serous surfaces; pallor of the organs; blood pale and watery; muscles a deep red color; some fatty degeneration of heart muscle, slighter in liver; bone marrow of femur fairly consistent, of a dull ochre color, with abundance of blood supply. Smears from the marrow suggested aplasia, showing very few cells of any kind, the most numerous being normal red

cells slightly paler, extremely scanty leucocytes, chiefly of lymphocytic or myeloblastic type, with reduced chromatin.

The second autopsy was made by Winternitz who found much the same changes except in the bone marrow which was markedly hyperplastic, but a deeper, darker red than is usual in hyperplasia; and smears showed aplasia, although not of quite so marked a grade as in Case 1.

Selling lays stress on three facts: the cases were in young girls, the course was essentially chronic, although in the end the serious symptoms developed suddenly; and the disease progressed in spite of withdrawal from the poison. These features were also true in Santesson's cases and are noted in many of the subsequent reports.

Following Selling's article came a number of reports of similar poisoning, several of them from the same industry and the same city as his. Thus McClure (21) in 1916 described a case of purpura hemorrhagica in a woman 31 years old who had been working in a Baltimore can factory. She had bleeding from the nose and mouth, and secondary anemia with black and blue spots over the body, and dyspnea. The red blood cell count was 1,460,000, white cells 1,110, hemoglobin 25 per cent, polynuclears 40 per cent, mononuclears 37 per cent, transitionals 15 per cent, no nucleated red blood cells, no myelocytes, and platelets almost absent. This patient was saved by the persistent use of transfusion; splenectomy was also performed. After the 13th transfusion, the red cell count rose to 5,280,000; and some fourteen weeks later the count was still 4,270,000. A year or so later a boy of 17 employed in the same sort of work was treated in the Johns Hopkins Hospital for purpura hemorrhagica and nosebleed. His blood count was as follows: reds, 2,272,000; Hb. 59 per cent; white cells 3200, of which 46 per cent were polynuclears, 34 per cent mononuclears, platelets greatly diminished. He was given five transfusions in the hospital and improved slowly, the improvement being very slow in beginning. He was discharged after two months with a red cell count of 4,030,000 * and white cells 7800, the platelets still reduced and the lymphocytosis still present. In that same year, a woman of 57, also employed in a can factory, died in the Johns Hopkins Hospital with bleeding from the nose, purple spots on the skin, bloody stools, hematuria, hemorrhage into the ear. At autopsy, erythroblastic hyperplasia was found and myeloblastic aplasia. The red cells were 4,784,000 and hemoglobin 100 per cent, while the white cells were 5480. The bleeding time was twenty minutes.

Hogan and Schrader's (22) three cases, with two deaths, are

* In these two cases the blood count was still low, after two months and after 3½ months. It is still a question whether the damage to the bone marrow is permanent. As is shown later, animal experiments point usually to complete regeneration but not always. (See Weiskotten.)

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also to be credited to Baltimore can manufacture. These occurred in the spring of 1922 and were reported in detail soon after. I give only the salient features of the cases.

All were employed in the same can factory and all developed within less than four weeks time. They formed part of a force of 58 who worked in the room where the bottoms are fastened to the cans by a rubber cement thinned with benzene. It is in the evaporation of the benzene by steam heat that the benzene vapors are formed, and in the factory in question the removal of these vapors was "lamentably insufficient."

Case 1 was a girl of 17 years who was admitted to the University of Maryland Hospital March 14, 1923, and died five days later. She had worked only six weeks in the "dope room." About March 4th she began to feel weak and lost her appetite, and on the 10th she had a headache and noticed bluish spots on arms and legs. By March 13th her mouth had become very sore so that she could hardly swallow, and the next day she was dizzy and spat blood. At the hospital she was found to be pale, undernourished, weak; and purpuric spots were found on arms and legs. She had shortness of breath, a hemic murmur over the heart, her mouth was sore, and there was bleeding from the vagina. Her blood examination on admission was: red cells, 1,240,000, anisocytosis and poikilocytosis, hemoglobin 39 per cent, white cells 600.

Transfusion of blood was practiced only once, and was followed by improvement, but on the fifth day after it the patient suddenly grew worse and died.

Case 2, a woman of 25 years, was admitted to the Maryland General Hospital March 7th with a diagnosis of placenta praevia and died on the 24th. An attempt was made to deliver her and a macerated fetus was obtained. No history is given, aside from the statement as to her employment in a can factory; but it is evident that there was a hemorrhage from the vagina. The blood count was as follows:

	Red Cells	Hemoglobin	White Cells
March 16th.....	470,000	19% 22%	1400
" 17th.....			538
" 20th.....			434 (following transfusion)
" 24th.....	900,000	12%	104

A differential white cell count on March 24th showed polynuclears 42 per cent, small mononuclears 56 per cent, large 2 per cent.

Case 3, a girl of 15 years, was admitted to St. Joseph's Hospital

April 9th, with a complaint of bleeding from the vagina and weakness. She had worked in the can factory five weeks and after three days she had a nosebleed. At the end of the first week, bleeding began from mucous membranes and she lost her appetite and felt tired after work. By the end of the second week her pallor was commented on by her friends. In another week, bleeding began from the vagina, which she took to be a menstrual flow, but it persisted till she came to the hospital, and for several days after. She vomited twice during the first day of this supposed menstruation, was so weak that she was obliged to give up work, suffered from headache, and her stools were tinged with blood. Physical examination was unimportant except for pallor of skin and mucous membranes, weakness, shortness of breath, and a hemic murmur over the heart.

Repeated blood examinations were made with these results:

Date	W.B.C.	R.B.C.	Hemo- globin	Small Lympho- cytes	Large Mono- nuclears	Polynu- clears
4-12-22	950	880,000	16%	52%	8%	38%
4-13-22	1200	930,000	17%	38%	4%	56%
4-14-22	1950	1,544,000	38%	46%	6%	46%
4-15-22	4700	1,985,000	42%	18%	4%	76%
4-18-22	3050	2,184,000	44%	40%	8%	50%

Transfusions were done on April 11th, 13th, and 15th. Her temperature ranged from normal to 102°-103° while in the hospital.

This last case is at once the most rapidly developing instance of chronic benzene poisoning in the literature and the most remarkable instance of recovery. Hogan and Schrader's cases also illustrate the peculiar danger of benzene in youth and in pregnancy.*

In a personal communication the following history came to me of a death from benzene poisoning in an employee of a can factory; but this time on the Pacific Coast. The victim was a woman, 41 years old, described as "always skinny and more or less sallow-complected" and with a goitre about the size of an orange. February 1st, 1922, she was put to work at the discharge of the retort where cans are heated after the ends have been coated with a rubber-benzene cement to drive off the solvent and dry the cement. She removed the warm cans and placed them in boxes. A down-suction draft provided by a fan had been placed here, and just above it was a pipe bringing in fresh air. Nevertheless, about March 16th she began to feel ill, was listless, complained of headache, then of

* One of the industrial insurance companies has sent me a statement concerning a fatal case of chronic benzene poisoning in a pregnant woman, 26 years of age, who also worked in a can factory.

nausea, and later of bleeding from nose and gums. She would feel fairly well in the morning, but as the day wore on (there was an eight-hour day) she would grow drowsy and at night she would suffer from severe headache and nausea. On May 11th a physician was called and found her suffering from nosebleed, bleeding from the gums, unusually profuse menstruation, and over the legs there was a heavy rash †, with here and there purpuric spots. She was taken to a hospital where examination showed hemoglobin 35 per cent, red cells 2,512,000, white cells 2,000. By May 24th the hemoglobin had fallen to 20 per cent, red cells to 1,000,000, and whites to 2,000. No young red cells were found. The rash had disappeared but purpuric spots appeared on the back. Transfusion of blood was practiced only twice, as her condition was considered hopeless. The exact date of her death is not given.

The rubber industry has contributed cases from many lands.

The Austrian factory inspectors' report for 1911 describes two deaths from an unusual illness in rubber workers characterized by purpuric spots on the body and found to be caused by fumes of benzene.

In 1909 the French Ministry of Labor issued a warning to rubber manufacturers against "benzene" fumes which, in a factory using rubber cement to fasten together rubber fabric and leather, had given rise to a number of serious accidents. The symptoms in these cases are described as pains in the liver region and a tendency to bleeding from the nose and mouth.

In 1921 in a French automobile factory the use of benzene rubber cement by six persons, in a hot unventilated room, was the cause of four cases of purpura hemorrhagica which developed in six months' time, and two of the victims died. The history of one of these, a woman, shows that she suffered at first from headache and dizziness. She became strikingly pale, then purpuric spots appeared over the body followed by acute anemia, fever, and death, within two months of the beginning of her exposure. (Flandin and Roberti (23).)

The late Dr. T. F. Harrington (24) of the Massachusetts Board of Labor and Industry published in 1917, the first American cases from rubber works. There were five cases of chronic benzene poisoning, all in men, and three of the men died. All had been using benzene cement in building auto tires, applying it by means of a cloth to the rubber. They would do this about eighteen times during an eight-hour day. Case 1, 33 years old, had worked eleven months. He soon began to suffer from severe headache, then he spat blood from his spongy bleeding gums, and spots like bruises appeared on his legs and arms and body. He had to give up work because of extreme weakness and breathlessness on slight exertion. After two

† Irritation of the skin or inflammation and itching was noted by Simonin.

severe nosebleeds, he came to the hospital with a pulse of 124; his red cells were 2,800,000, hemoglobin 60 per cent, white cells 500. Transfusion of eight ounces of blood was followed by uncontrollable nosebleed which recurred daily. He had headache, vertigo, restlessness, delirium, and loss of power in arms and legs. Coma, convulsions, and death occurred on the eleventh day after he entered the hospital. At this time his hemoglobin had fallen to 35 per cent, red cells 1,616,000, white cells 850, of which 62 per cent were small mononuclears and 14 per cent polynuclears. The second patient had much the same history, and in addition hemorrhage from the bowels. He had worked for six to seven months. The third was more resistant, working for two years before he was severely poisoned. His first symptom was the appearance of red spots on the skin. At death his red cells had fallen to 944,000. After the factory had substituted naphtha for benzene they had no further trouble of this sort. Recently a statement was made to me by an insurance man to the effect that seventy cases of benzene poisoning developed in a rubber works and three of them were fatal.

According to Legge (25), the first known cases of chronic benzene poisoning in Great Britain occurred in rubber work and came to light in January, 1918. Two men, both healthy and young, 29 and 30 years old, were employed in spreading balloon fabric with rubber dissolved in pure crystallizable benzene. Formerly coal-tar naphtha, *i.e.*, a mixture of benzene, toluene, xylene, etc., had been used. Both men sickened after about three months' exposure, one dying a week after, the other in three weeks. Their clinical history was practically identical, beginning with malaise and anemia, followed by hemorrhages under the skin and from the mucous membranes, and later from the nose, gums, and bowels. At autopsy the chief findings were submucous hemorrhages throughout the intestinal tract and hemorrhages under the endothelium of the heart. In one case the characteristic changes of aplastic anemia were found in microscopic examination of the marrow of the long bones. Estimation of the benzene content of the air in the factory showed that it contained at various places in that room from 2.1 to 10.5 parts per 10,000 of air.

Two recent cases in German rubber manufacture are, according to Brücken (26), the first instances of chronic benzene poisoning noted in that country. They were young women using benzene rubber cement to fasten together the two halves of rubber balls, working in a room kept hot and draftless for fear of injury to the product. After working about two and a half years, No. 1, a woman 22 years old, began to feel ill, found it hard to climb stairs, suffered from headache and somnolence. Six months later, when Brücken first saw her, she complained of violent headache, great exhaustion, palpitation of the heart and cough. He found a

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temperature of 101° F. and a weak, rapid pulse, 100 per minute. A diagnosis of grippe was made, but while the cough and headache subsided, fever and rapid heart action persisted, exhaustion increased, and her pallor was striking. He then elicited a history of excessive menstruation, coming on every three weeks and lasting 8 to 10 days; and the fact that the lightest blow produced big black and blue marks on the skin; while bleeding from the gums was frequent, and occasionally blood came with the stools. A blood examination showed Hb. 26 per cent (Sahli), very striking leucopenia, few platelets, striking anemia, polychromasia and anisocytosis, but no normoblasts. Bleeding time was very prolonged, the drops continuing to flow without any diminution for 16 minutes, when the observation was broken off. Treatment brought about no improvement for some time, temperature persisted at 100-101, bleeding from gums and intestines and two periods of excessive menstrual flow brought great exhaustion, the patient sleeping practically all the time. At the end of four weeks in bed improvement began, and at the end of two months more, convalescence was well established. The blood counts at the beginning and end were as follows:

	Hb.	Color Index	R.B.C.	W.B.C.	Platelets	Bleeding time	Neutrophils	Lymphocytes	Mononuclears	Eosinophils
Feb. 14 ...	32%	1.05	1,515,000	6,833	24,240	16 min.	48%	42%	10%	...
April 22 ...	81%	1.02	3,990,000	2,460	155,610	2 min.	69%	24%	6%	1%

The second case, in a woman 23 years old also employed at this work for three years, was much less severe. The symptoms were similar, malaise, frequent headache, bruised spots on slight injury, menstruation at shortened intervals. Examination showed mottling of the skin of the arm. The blood findings were: Hb. 43 per cent, slight polychromatophilia and anisocytosis; differential count of whites, neutrophils, 47 per cent, lymphocytes 38 per cent, mononuclears 12 per cent, eosinophils 3 per cent.

The city of Milan, which is the center of the rubber industry in Italy, has been the scene of serious benzene poisoning among young women employed in cementing the seams of rubber raincoats. According to Meda (27), in one factory in the winter of 1921 three women died from this form of industrial poisoning and the following March a number of cases developed in another factory and four girls died, with "very severe anemia hemorrhagica of the aplastic type," the rest recovering after a fairly long period. Pugliese (10) says that in the latter factory the air contained one part of benzene per thousand. Meda describes the factory as being modern in construction, operating for only one year and supposedly beyond criticism so far as factory hygiene is concerned. The best commercial benzene was used.

One hundred women, mostly young, were employed in one room cementing seams with a solution of rubber and benzene and wiping off the excess with pure benzene, each having therefore two benzene receptacles on her bench. Many of these women had done the work for several years and no trouble had been experienced but, either because of some change in the composition of the commercial benzene, or perhaps an increase in the density of the vapors (all the Milan cases occurred in winter), poisoning developed. Meda notes that benzene poisoning seems always to appear in sporadic, sudden epidemics, according to the literature. The victims in these factories were probably predisposed to poisoning by something which lowered their resistance and such factors are chlorosis in young girls, tuberculosis and pregnancy. Women are certainly far more susceptible than men.

Of the seven severe cases in 1922, four died and three slowly recovered. The history of one of these latter is given in detail. This was a married woman 25 years old, unusually vigorous and well nourished, who had done similar work for seven years. She was, however, pregnant at this time. In February, 1922, she began to have headache, dizziness, somnolence, nausea, and pain in the epigastrium which she attributed to a change in the cement, for she had noticed that it had a different odor. She grew very pale and thin; she had bleeding from the gums, and finally hemorrhagic spots over the body. She was now in the eighth month of pregnancy, she left the factory, had repeated nosebleeds before delivery, and after her delivery which was normal, she had an outburst of purpuric spots and of hemorrhages, with great weakness. She then came to the hospital with a temperature of 37.6°C ., pulse 120, small, soft and regular, respirations 24. The urine contained albumin, indican and a few granular casts and epithelial cells; the red blood cells numbered 1,700,000, whites 1,700, hemoglobin 29 (Fleischl), and there was a marked loss of platelets. The differential count of whites gave polynuclears 54, mononuclears 13, lymphocytes 33; the blood coagulated slowly and without contraction of the clot. Ten days later, the red count was only 600,000 and the hemoglobin down to 15 per cent, but the whites numbered 3,000; there were no platelets and no youthful forms. The patient then developed a pyelonephritis, with a typical temperature curve, the white cell count rose to 7,300 and suppuration was abundant. Meda emphasizes this fact and thinks that the suppurative process was favored by the lowered resistance of the patient but that it also acted as a stimulant to the blood-building tissues.

As the temperature fell, the patient passed into a condition of profound weakness, delirium or stupor, and the white cell count fell to 2,000. Injection of autogenous vaccines cleared up the pyelitis and young blood cells appeared. By the middle of August

recovery had set in, the red cell count was 3,000,000, the white cells 5,500, with a normal leucocytic formula, the hemoglobin was 60 per cent and there were many platelets. Meda considers that the striking facts in this history are the vulnerability to benzene which is caused by the condition of pregnancy, breaking down the resistance of an unusually vigorous woman who had been exposed to it for seven years; the lowered resistance to infection brought about by the benzene poisoning as shown in the infection of the pelvis of the kidneys. He emphasizes the fact that the literature of chronic benzene poisoning consists of single observations on the clinical history and pathological anatomy of individual cases and that there is as yet no comprehensive study of the etiology and prevention of industrial benzene poisoning.

Pugliese (10) studied these same cases in Milan. He says that serious cases of poisoning with loss of consciousness occurred in workers exposed to two or three parts of benzene in ten thousand of air. The symptoms in slight cases were headache, nausea, abdominal pains, dizziness, sensations of chilliness and formication, rapid fatigue, loss of appetite, loss of strength, and breathlessness. Lesions of the skin consist of dryness or an itching erythema or eczema, conjunctivitis, blepharitis, or even keratitis. There may be a polyneuritis, and sometimes a retrobulbar neuritis. In the urine he has found albumin, casts, droplets of fat, hemoglobin and conjugated sulpho bodies. The anemia may continue to increase after the woman is removed from work.

Two cases of fatal purpura hemorrhagica caused by benzene fumes were brought before the New York State Workman's Compensation Commission in 1920. The men had been employed on a machine for coating fabrikoid, which is thus described: the fabric is fed in from the front to an endless traveling apron, which carries it over heated pipes. The coating mixture runs down from a can suspended above a 4-inch (10 cm.) hole in front, and the whole is encased in a wooden box. The temperature inside the machine is sufficient to volatilize all the solvent. The coating mixture consisted at that time of nitrocellulose, pigment, castor oil, grain alcohol, benzene, and ethyl acetate. Fumes escaped from the hole in front, but still more at the back, where the hot, coated fabric left the machine. From evidence given at the hearing, it seems that nosebleed among the men in this department was of fairly frequent occurrence, and that the labor turnover was great. They worked on eight-hour shifts, sometimes, but "not very often," sixteen hours.

Both of the men who died were young and had always been strong and vigorous up to the time of their last illness. The first one worked for about nine months before he began to have bleeding from the gums, and noticed small, red blotches on the skin between the ankles and the knees. Three weeks later, March 21, he had a

severe nosebleed. He was taken to the hospital, March 24, and died April 7, after repeated nosebleeds, bleeding from the mouth, temperature over 101° F. and the appearance of purpuric spots all over the legs up to the waist. The second man worked for less than six months, sickened February 17, and died March 9. He had been feeling ill, complaining of the poor ventilation in the shop and of loss of appetite, and was very pale. Then, on the night shift of February 17, he had what one fellow workman called a chill and another a convulsion, his nose began to bleed, and the blood oozed from his gums. Evidence given by his physician was that from then up to his death he had continual bleeding from the nose and mouth, bruise-like blotches appeared on the legs and body, and the temperature ranged from 102° F. to over 104° . In neither case was any blood examination made, and the medical details are very scanty.

The company had made tests of the air around the coating machines; for it was anxious to prevent the escape of the solvent, which it was desirable to recover for use again. Something less than 5 per cent was reported to be the highest concentration of benzene found in the air, and it is evident that the officials considered this amount too little to cause any anxiety. A personal communication from Canada informed me of a death from benzene poisoning which occurred in a fabrikoid factory, in a man of 50 years.

Newton (28) of Akron, Ohio, and Starr (29) of Columbus, Ohio, have given very valuable data concerning the early stages of slow benzene poisoning. Newton examined three chemists who had been exposed to benzene vapors for about two weeks. Only one complained of ill health, headache, lassitude, anorexia and loss of weight, and then of a sudden attack of pain in the abdomen, nausea and vomiting. Newton found the pulse and temperature normal; but there was a marked leukopenia, 1200 whites, with 39 per cent of them large mononuclears. The erythrocyte count was 5,760,000, but the hemoglobin, only 80 per cent. He then examined the blood of the other two and found white counts of 1250 and 1700, and a low red count, from 3.6 to 4 million. Appropriate treatment resulted in a decided increase in the white cell count, which shows the value of periodic examinations of the blood in workers exposed to benzene.

In this connection it may be noted that Selling (20) examined the other employees in the room from which his cases had come, 5 men and 15 girls, and found purpuric spots on the skin in four, two men and two girls, none of whom complained of illness. Their blood showed a slight grade of anemia and a leucocyte count varying from 3,900 to 5,200 which was somewhat lower than the average (5,200 to 6,000) for those working in other parts of the factory.

An investigation made by the late E. B. Starr (29) of the Ohio State Department of Health brought to light a new source of benzene poisoning in industry, the use of benzene cement in wholesale mil-

linery establishments. Starr had an unusual opportunity to study the early symptoms of benzene poisoning among some 31 girls who were employed in spreading cement on cloth and pasting it on buckram hat crowns. Up to eight years ago such pieces were always sewed together, then cement was introduced, but it was only in the fall of 1921 that any trouble from its use was observed, and then it was found that a change had been made in August in the composition of the cement. Analysis carried out by the Department of Health showed the following constituents in the solvent, the percentages being given by volume:

	Sample A	Sample B
Carbon tetrachlorid	70 per cent	66 per cent
Benzene	30 " "	34 " "
Carbon disulphid	0 " "	0.05 " "

Twenty-seven of the women employed handled cement, and of these twenty-two had definite symptoms, and in addition two out of the four who worked near by were somewhat affected by the fumes. The symptoms consisted in soreness and burning in the throat, sometimes in the eyes; burning in the epigastrium; nausea; vomiting; frequent urination; giddiness; slight air hunger; and a feeling of weakness. It is noteworthy that the symptoms usually increased during the evening after leaving the factory. An itching inflammation over the forearms was sometimes present. Starr was not able to elicit any history of disturbance of menstruation and only one woman had purpuric spots, which disappeared after a month's time. Pulse and heart action seemed normal. A conspicuous symptom was burning in the epigastrium with tenderness on pressure. One of the women in this group had recently died and benzene poisoning was suspected but investigation showed that death was due to a perforating gastric ulcer. Starr, however, calls attention to some experiments of Weiskotten and his colleagues who found in three animals exposed to benzene vapors, hemorrhages into the gastric mucosa and in one of them small ulcers. (See also Chassevent and Garnier (5), page 478.)

A review of all these instances of chronic benzene poisoning in industry fails to throw much light on the danger limits of benzene vapor in the air of a working room. The men in the American fabrikoid factory died after several months' exposure to air containing, according to the company chemist, something under 50 parts per 1,000. Pugliese found only one part per 1,000 in an Italian factory where fatal cases had occurred, and symptoms of poisoning appeared in an atmosphere of 0.2 to 0.3 parts per 1,000. Legge tells us that as little as 0.2 to 1.0 part per 1,000 was present in the English balloon factory where two men contracted fatal ben-

zene poisoning. There is need of a great deal of close observation with analysis of air and probably periodical examinations of the blood of the men and women employed, before this question is definitely settled.

There are certain very puzzling features about benzene poisoning in industry. Some factories use large quantities apparently without any damage, others have deplorable results from much slighter quantities. For instance, I know of one factory employing from 60 to 80 men in an atmosphere heavy with benzene fumes. These men spread a benzene dope over wide surfaces, leaning over the table as they work and using the dope lavishly. They then stand the painted material at one end of the room to dry, and the temperature is kept high to hasten drying. The men have been for two years under the observation of an unusually alert and scientifically trained physician, yet he has never been able to detect one case of poisoning.

In all the epidemics of benzene purpura in the literature there have been some puzzling features. Individual susceptibility of course varies greatly. Lehmann, Weiskotten, Drinker and Hurwitz, and others find that animals show very different degrees of sensitiveness to benzene, from a slight leucopenia to complete disappearance of white cells. Yet this is not enough to explain a sudden outbreak of poisoning in certain individuals of a group which has been exposed a long time to the fumes, without any increase of exposure. It may be that closer study of such occurrences may reveal decided alterations in the composition of commercial benzenes, variations unsuspected by the purchaser. The women in Dworetsky's Russian factory had noticed such a change, as had also those in the Ohio factory investigated by Starr, and the Italian women in Meda's raincoat works.

Benzene has an effect on the skin which probably is traceable to its solvent action on the natural fats of the skin. Painters often suffer from it and, in a recent report from Germany, the men engaged in painting agricultural machinery suffered from a painful itching and burning rash which was traced to the benzene used as a substitute for turpentine and linseed oil. The most widespread trouble of this sort that I have seen was in a factory making leather upholstery and automobile tops by coating leather with a solution of nitrocellulose in benzene, amyl acetate, and butyl acetate. Of the 60 men employed, not one had escaped. Some suffered from severe furunculosis, others from redness and tiny blebs which sometimes became infected, forming small ulcers. Anointing with an animal fat before and after work seemed to be the best preventive.

Pathology of Chronic Benzene Poisoning.—Selling's cases and the animal experiments performed by him in confirmation of his findings led to a long series of experimental studies on the action of benzene, partly because of Koranyi's suggestion that its hematoxic

action might be utilized in the treatment of leukemia, partly because the direct action of benzene on the blood-forming tissues makes it a useful agent for the student of blood pathology and of immunology.

Selling's animal experiments had shown that benzene is a powerful leucotoxin, destroying the white cells of the circulating blood and the parenchymal cells of the blood-forming organs—bone-marrow, spleen, lymphatic glands, and the lymph follicles in the appendix—the myeloid tissue suffering more damage than the lymphadenoid and the polynuclear cells more than the lymphocytes. The erythroblastic tissue of the bone-marrow is destroyed, but the circulating erythrocytes are injured relatively little. The pathology of benzene poisoning is essentially an aplastic anemia. No nucleated reds or abnormal reds are found, platelets are absent or scanty, and there is polymorphonuclear leucopenia. Selling found that while benzene destroys the specific cells of the bone-marrow, causing extreme aplasia, there is at the same time an irritant action, and, for a while, the two actions go on simultaneously. If the injections are stopped at a point when the blood-forming organs are almost wholly aplastic, regenerative changes begin within a few days and are complete in ten days to three weeks, the blood picture also approaching the normal.

Some of the work of Weiskotten (30) and his colleagues has a decided bearing on industrial benzene poisoning, although it was done in connection with the therapeutic use of benzene. His first experiments were carried on with subcutaneous injections of benzene in olive oil. A fall in the leucocyte curve occurred and at this stage the rabbit might die; but if it survived, there was a rise of leucocytes to the normal level, then a secondary fall almost always as low as the first, sometimes lower; and this was followed by a secondary rise if the animal did not die, but the mortality was as great during the secondary fall as during the primary. A single dose of benzene brought about this series of reactions. A return to normal would occur even after a high degree of leucopenia. This had been noted also by Selling who reduced the leucocytes in rabbits almost to the vanishing point, yet saw them return to normal count. Weiskotten (31) has also found that the results of exposure of rabbits to benzene vapor are of the same general nature as those produced by subcutaneous injection of olive oil-benzene mixture. Maximal sublethal dosage causes leucopenia, hemorrhages, and slight anemia. After discontinuance of the exposure, the total leucocyte curve rises to a permanent general level, lower than that existing before exposure. This relative leucopenia is permanent. The percentage and absolute decrease of the small mononuclears is greater than that of the polynuclears, and the small mononuclear curve does not rise to its former level.

Experiments with guinea-pigs made by Fontana (32) showed that a daily injection of 1 c.c. per kilogram for four to ten days resulted in death with almost complete disappearance of the leucocytes, reduction of hemoglobin to about one-tenth, and a fall in the red cell count to about 3,000,000. He found that the lymphocytes survived longest except in the most rapidly developing cases when this inversion of the leucocytic formula did not occur.

The irritant action of benzene noted by Selling, probably accounts for the findings of several investigators who used very small quantities of benzene. Thus Langlois and Desbouis (33) experimenting with small quantities of benzene administered in vapor form provoked a leucocytosis in guinea-pigs and pigeons, less marked in rabbits and dogs, lacking in cats. There was also a slighter increase of the red cells. This result was due to stimulation of blood formation, not to loss of plasma, and the effect lasted only two days after discontinuance of the exposure. In some cases they observed a slight diminution in the white cells, which they considered accidental.

Eosinophilia, as the only pathological change in the blood, was noted in benzene workers by Agasse-Lafont and Heim (8). They examined workmen who had been exposed to commercial benzene from a few months to six years and found no change in the blood except eosinophilia which was present in 80 per cent and appeared in the early months of exposure, disappearing soon after exposure ceased and bearing no relation to the intensity of the clinical symptoms. The same thing was found by Simonin (15) in a case of acute intoxication with fever, eruption, and bronchial catarrh. There was an enormous eosinophilia, of 25 per cent, on the fifth day, dropping to 2.5 on the thirteenth.

The hemorrhagic features of benzene poisoning were studied by Duke (34) who brought about a rapid rise in the platelet count by injection of benzene in rabbits, followed by a rapid fall. When three doses only were given, the rise was gradual and did not fall subsequently below normal; but in animals receiving five doses the fall was marked, and purpura hemorrhagica and severe anemia, with aplasia of the bone-marrow developed. Fontana (32) noted a marked fall in platelets in about half of his animals (guinea-pigs).

Hurwitz and Drinker (35), following up the work of Selling and of Duke, produced aplasia of the bone-marrow in rabbits by injecting 2 c.c. of pure benzene per kilo daily. Not only were all the formed elements of the blood markedly reduced, but also the factors of blood coagulation, the circulating prothrombin being considerably less than normal.

The fact that Selling's experiments show a selective action of benzene on the tissues and cells that are concerned in the production of antibodies and in defense against infection, led Hektoen (9) to investigate its influence on the course of infection in animals.

He found in rabbits a depression of antibody formation, a reduction of precipitin and lysin, together with grave lesions in the marrow, leucopenia, and reduction in the phagocytic power of the leucocytes. He concludes that "benzene may lower the resistance to infection by reduction (1) of antibody production, (2) of the number of leucocytes, and (3) of leucocytic activity." Two years before, Rusk (36) had found that rabbits, when poisoned with benzene, produced hemolysins and precipitins much less efficiently than normal animals.

Weiskotten (37) made some observations in the course of one of his series of experiments, which go to confirm the findings of Rusk and of Hektoen. During daily subcutaneous injections of olive oil-benzene mixture, in four rabbits, he noticed the development of active acute infection and in at least two of these it seemed that infections present before the injections began were "lighted up" as a result of the injections. In these animals a polymorphonuclear leucopenia did not appear, in fact there was the usual leucocytosis of acute infection and the animals died at the height of their leucocytosis. Weiskotten concludes that the leucocyte count cannot be safely depended upon in connection with the administration of benzene.

As for organic changes, Chassevent and Garnier (5) found in the guinea-pig congestion of the peritoneum and of the abdominal organs, ecchymoses or ulcerations in the gastric mucosa, at the niveau along the artery. Klemperer and Hirschfeld (38) found more or less severe marrow destruction and severe and extensive necrosis of liver and kidneys. Selling found fatty changes in liver and kidneys, and hemorrhage into lungs, pleura, and stomach. Neumann (39) found in rabbits dying within 21 to 33 days after repeated injections of benzene-olive oil, hyperemia and pigmentation of the liver; spleen very hyperemic, aplastic, rich in pigment; marked hypoplasia of the bone-marrow which was also hyperemic and rich in pigment. Like all observers he found a marked variation in the lesions in different animals. Fontana noted diminished volume of the spleen in all animals dying of chronic benzene poisoning.

Two more suggestive observations on benzene deserve mention. Schiff (40), working in Heffter's laboratory in Berlin on the nature of anaphylactic shock, found that small doses of benzene which caused only a slight leucocytosis would increase sensitivity to anaphylaxis toward sheep serum, while large doses, causing leucopenia, would lower sensitivity. Jaffé (41) isolated an N-free acid from the urine of dogs and rabbits after feeding them a long time with benzene, which he identifies with the "Muconsäure" of Rupe and which has the formula $C_6H_6O_4$. The amount found is small, representing only a fraction of the benzene administered, as for instance 0.2 mg. in the urine after 60 gm. of benzene had been administered.

The urine has the characteristics of carbolic acid urine,—dark, almost black in color.

The changes caused by toluene are far less marked and characteristic than those of benzene. Hektoen (9) found that the effect of toluene in repeated doses of about 1 c.c. per kilo lessens antibody output in the earlier stages of antibody production, but under certain conditions causes prolonged persistence of antibody in the blood. The effect produced by benzene on the white blood cells is absent in toluene poisoning, and there is no immediate change as to number, proportion, or phagocytic activity of these cells. Mary W. Brown, in Hektoen's laboratory, found that repeated injections of toluene in rabbits cause a hyperplasia of the myeloid cells of the bone-marrow and a phagocytosis of leucocytes by the giant cells, without a coincident increase in the cells of the circulating blood or changes in liver, spleen or appendix.

To summarize briefly: the effect of chronic benzene poisoning is to cause a loss of red blood corpuscles, resulting in profound anemia; a loss of the elements and substances in the blood which are concerned in blood clotting, resulting in hemorrhage; and a loss of white blood cells and of the substances in the blood serum which are concerned in defending the body against bacterial infection.

A very valuable report has recently been returned by a special committee of the National Safety Council which was appointed in 1923 to study benzene (benzol) poisoning in industry. Their first report has already been mentioned in this chapter, and the manuscript of the 1924 report is now at hand, covering the work done in 1924 with the coöperation of the Hood Rubber Company and the Massachusetts State Department of Labor and Industry. The Committee has collected records of 98 cases of benzene poisoning, 15 of them fatal. Of these, six were of acute poisoning with four deaths, 92 were of chronic poisoning with 11 deaths. In addition two firms reported "several cases of illness."

The Committee studied the methods of use of benzene in industry, of fume removal, and of the actual concentration in the air of the plant and the effect of benzene vapor on the workers as determined by symptoms and physical findings, particularly the findings in the blood. For estimation of the benzene content of the air they utilized activated charcoal prepared according to the standard procedure recommended by the U. S. Bureau of Mines, a method which is claimed to be the most accurate one in use for field work, yielding amounts about 8 to 10 per cent lower than the existing condition.

The benzene-using industries studied fall into two classes. In the first large amounts are used but in a closed apparatus so that except through an accident to the piping system there is no escape of fumes. In this group chronic poisoning will probably not occur, but there is

always danger of acute poisoning which may take place with little warning. Such industries are the production of benzene and motor fuels by distillation of coal and coal tar, and the chemical industries such as oil extraction, dye and dye intermediates, making paints, varnishes and stains and varnish and paint removers. The second group is much more important, for benzene is used as a solvent or vehicle and as a part of the process the benzene must be removed by evaporation, sometimes hastened by heat. In this class come: the rubber industry, making artificial leather, making sanitary cans, dry cleaning, and the use of paints, varnish and stains and paint and varnish removers.

Seventy-eight plants were inspected by field investigators, and in 14 conditions were found satisfactory for an intensive investigation as outlined above. Five were rubber works, three making artificial leather, two making sanitary cans, and one each making paint and varnish remover, insulating electric wires, recovering benzene, and dry cleaning. Twenty-three clinical cases of benzene poisoning had already been recognized in these plants.

Eighty-four workers were examined for signs of early benzene poisoning, the blood count being accepted as the most important early diagnostic sign. They took as a standard a count of 7,500 white cells and a loss of 25 per cent as probably suggestive of poisoning. On this basis 13 suspicious cases were revealed, 12 with a low white count and one whose white count was only slightly lowered but the hemoglobin was far below normal. The tabulation of these cases show hemoglobin running from 23 per cent to 85 per cent, no less than four being as low as 30 per cent; red blood cells, from 800,000 to 5,424,000; white counts from 1,450 to 6,140. Of the latter, one was between 2,000, and 3,000, five between 3,000 and 4,000, four between 4,000 and 5,000, two between 5,000 and 6,000, and one between 6,000 and 6,500. The loss was most marked in the polynuclears.

"It seems to us somewhat significant that out of 84 men employed in processes involving more or less continuous exposure to benzene fumes, 13, or about 15 per cent, should have shown a blood picture strongly suggestive of benzene poisoning. This would appear to confirm the conclusion of our previous report that the benzene hazard in industry is a real, but not a sensational, one. In one dry cleaning plant, however, two out of the three men examined showed this condition, and in an electric insulating plant four out of nine were thus affected." The physical findings and symptoms were very slight, as in Newton's cases, showing that marked changes in the blood cells may occur before subjective symptoms begin to appear. Only four out of nine suffered from dizziness, yet that was the most frequent complaint, one had nosebleed, and six showed pallor. Headache and loss of appetite were complained of in two cases.

The committee found a distinct relation between exposure to benzene fumes and symptoms of early poisoning. Determination of the amount of benzene gave values ranging from 28 to 4,140 parts per million. The variations which occur from time to time in the same plant, especially in summer with the windows open, are very great, but as a general thing where an efficient system of local exhaust ventilation was at work less than 200 parts of benzene vapor per million of air was found, and no abnormal blood counts were observed in workrooms provided with efficient local exhaust ventilation.*

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*The report is signed by C.-E. A. Winslow, Chairman, L. Greenburg, Vice-Chairman, J. W. S. Brady, L. E. Weber, W. S. Paine, C. F. Horan, H. Bradshaw, and J. M. Weis.

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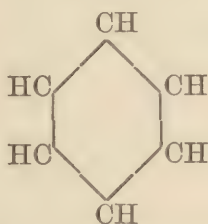
CHAPTER 34

BENZENE DERIVATIVES

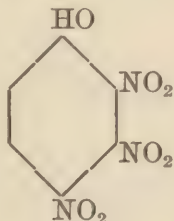
DERIVATIVES OF THE COAL TAR SERIES

THE chemistry of this group is complicated and yet it is impossible to understand the physiological effects of the different compounds without some knowledge of their chemical structure. I have therefore arranged as simply and briefly as possible the essentials of the organic chemistry of the coal tar series.

Structure of the Benzene Ring and its Principal Derivatives, Isomeric Forms, Etc.—The benzene molecule is for convenience represented by a "ring" or hexagon which, if unmodified, stands for C_6H_6 , or



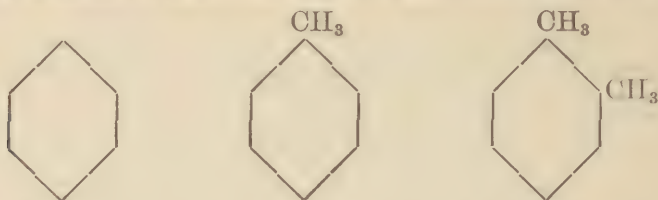
Usually the carbon and hydrogen elements in a graphic formula are not written out, for it is understood that all replacements for the formation of new compounds take place at the expense of the hydrogen atoms and that no matter how complicated a series of such replacements may be, the original 6 carbon atoms of the ring remain unaltered. To illustrate, the formula for picric acid, trinitrophenol, is usually written thus,



and the unoccupied angles of the hexagon are understood to be taken by the original hydrogen atoms.

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Benzene is C_6H_6 . Toluene is methyl-benzene, $C_6H_5CH_3$. Xylene is dimethyl benzene, $C_6H_4(CH_3)_2$. The graphic formulas are these:



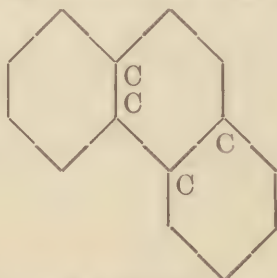
In naphthalene, two benzene rings are joined directly together, at the expense of two hydrogen atoms, which results in the formula $C_{10}H_8$ or



Anthracene is three such rings joined together, or $C_{14}H_{10}$.



Phenanthrene has the same number of atoms as anthracene and its formula is also $C_{14}H_{10}$, but the three rings are differently grouped.



When the hydrogen of the benzene ring is displaced by HO, phenols result:

C_6H_5HO , hydroxybenzene, or phenol or carbolie acid.

$C_6H_4(HO)_2$, dihydroxybenzene or resorcin.

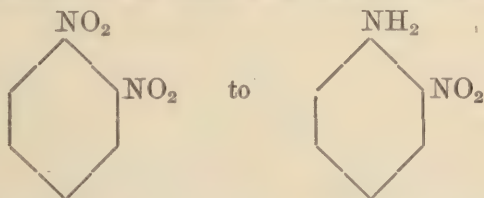
$C_6H_3(HO)_3$, trihydroxybenzene or pyrogallie acid.

$C_6H_4CH_3HO$, hydroxytoluene or cresol.

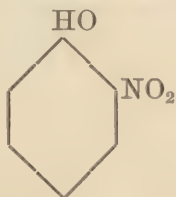
The introduction of the nitro group into the ring produces nitro compounds, such as nitrobenzene, $C_6H_5NO_2$, and dinitrobenzene,

$C_6H_4(NO_2)_2$: nitrotoluene, $C_6H_4CH_3NO_2$, and trinitrotoluene, $C_6H_2CH_3(NO_2)_3$; nitronaphthalene, $C_{10}H_7NO_2$, and dinitronaphthol, $C_{10}H_5HO(NO_2)_2$.

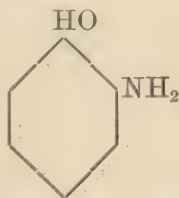
Reduction of a nitro compound changes the NO_2 radical to NH_2 and produces amido compounds. From nitrobenzene comes amido-benzene or anilin, $C_6H_5NH_2$. From nitrotoluene comes amido-toluene or toluidin, $C_6H_4CH_3NH_2$. From nitroxylenes comes amido-xylene or xylidin, $C_6H_3(CH_3)_2NH_2$. The reduction may be partial, as when dinitrobenzene is reduced to nitranilin, thus:



and this may be further hydrolyzed to nitrophenol:



and then reduced to amidophenol:

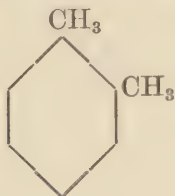


For convenience the angles of the benzene hexagon have been numbered in the order of the figures on the face of the clock.

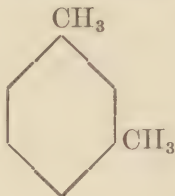


When only one hydrogen atom is replaced by a new atom or radical it is of no importance which of the six is replaced, but

when more than one is substituted, several so-called isomers or isomeric forms are produced, bodies which have the same number of the same atoms, but are differently grouped and differ decidedly from each other in physical properties and in toxicity. For instance there are three xylenes, or dimethylbenzenes, $C_6H_4(CH_3)_2$.



Orthoxylene.

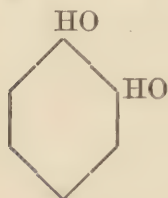


Metaxylene.

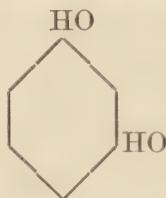


Paraxylene.

There are three dihydroxybenzenes, $C_6H_4(HO)_2$.



Ortho, or pyrocatechin.

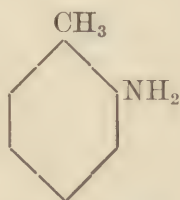


Meta, or resorcin.



Para, or hydroquinone.

Orthotoluidin,



is an oily liquid at a temperature at which paratoluidin

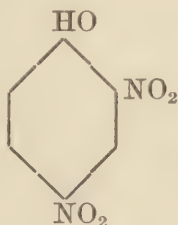


is crystalline.

The prefixes commonly used, ortho, meta, and para, refer, then, to the different forms which result from the displacement of two of

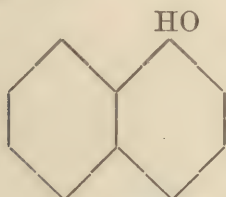
the hydrogen atoms of the ring. When there are more than two substitutions, a much greater number of isomeric forms is possible, and these are designated by the numbers of the angles, 1-2-3, 1-2-4, 1-3-5, etc.

Dinitrophenol 1-2-4 is this:



It differs toxicologically from all the other isomers.

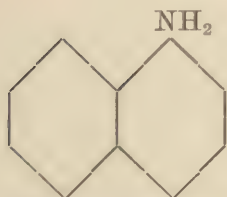
When two or more benzene rings are joined, as in naphthalene, two mono-substitution products are formed, according as the substituting atom or radical is combined with a carbon atom, which is in direct union with one of the common carbon atoms, or not. These two forms, known as alpha and beta, may be illustrated as follows:



Alpha-naphthol.



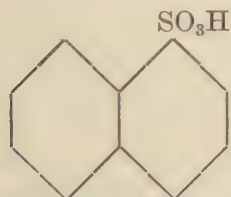
Beta-naphthol.



Alpha-naphthylamin.



Beta-naphthylamin.



Alpha-naphthalene-sulphonic acid.

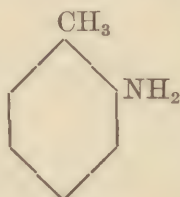


Beta-naphthalene-sulphonic acid.

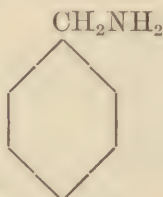
The compounds thus far described are all substitution products formed by replacement of the hydrogen of the ring. They differ in chemical and physical properties and in their effect on human beings from the substitution products which are formed by displacement of hydrogen from a side chain, such as the radical CH_3 . Thus, if the hydrogen of the ring in toluene is displaced by NH_2 , amidotoluene or toluidin, is formed, while if the replacement takes place in the CH_3 radical, we have benzylamin. A third compound, with the same elementary composition, results when the replacement is in the NH_2 group of amidobenzene, or anilin, and a CH_3 radical enters. This last is methyl anilin. These three compounds are very different in action and in properties.



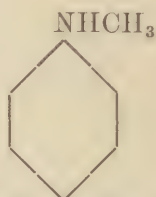
Toluene.



Orthotoluidin.

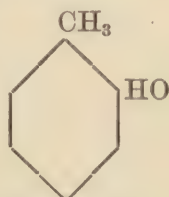


Benzylamin.

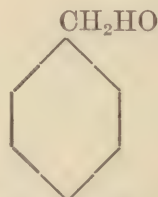


Methyl anilin.

This distinction is very important, for the ring substitutions have in general the physiological action of benzene, while many of the products formed by replacement of hydrogen in the methyl group act like the alcohols. The following are some instances of these two kinds of products: *

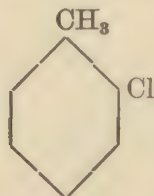


Orthocresol.



Benzyl alcohol.

Chlortoluene, formed by chlorin gas in toluene with heat, is



* Substitution products of toluene are usually called tolyl or toluyll compounds. Toluyllendiamin is $\text{C}_6\text{H}_4\text{CH}_3(\text{NH}_2)_2$. Side-chain products are called benzyl. Benzaldehyd is $\text{C}_6\text{H}_5\text{CHO}$.

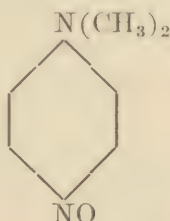
Benzyl chlorid, formed by chlorin gas in toluene with cold, is



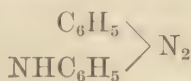
Bodies similar to benzene substitution products may be formed from ammonia, H_4N , by substitution of one of the hydrogen atoms. Anilin is $\text{C}_6\text{H}_5\text{NH}_2$. Diphenylamin is $\text{NH}(\text{C}_6\text{H}_5)_2$.

These ammonia substitution products are slightly toxic if at all.

An instance of a body which is both a substitution and an addition product is nitrosodimethylanilin



When an amido compound of the benzene ring is acted on by nitrous acid, HNO_2 , there results a series of intermediate compounds known as diazo compounds, which contain two nuclei bound together by $\text{—N}_2\text{—}$. Diazoamidobenzene is



Anilin, para- and meta-phenylendiamin, etc., yield these diazo compounds and the latter unite with other amido compounds or with phenols to form azo coloring matters. For instance, the diazo compound of benzidin acting on alphanaphthylamin and sulphuric acid forms Congo red. The diazo compounds are not poisonous.

For industrial use the most important derivatives of benzene and toluene are the nitro, amido, diamino, and chlor compounds; for these are the so-called intermediates used in the production of coal-tar dyes, drugs, and perfumes, and some of them are also used as accelerators in the vulcanization of crude rubber. The danger accompanying their use in industry depends not only on their chemical structure, their actual toxicity, but on their physical structure, solids being less dangerous to handle than fluids, and those that volatilize readily being attended with much more danger than those which do not. Another important factor is the way a given com-

pound is handled. A study of the sickness records in a dye works would show that the compounds responsible for the greatest amount of industrial sickness are not necessarily the most toxic, but are those whose use requires more exposure of the workman to contact or to fumes. For instance, mononitrobenzene does not give rise to nearly so much poisoning as dinitrobenzene, yet it is a fluid, while the latter is a solid, but dinitrobenzene has to be transported much more and handled in the open and therefore it always causes much more poisoning.

Following is a brief statement of what is known as to the relation of chemical constitution to physiological action in the coal-tar or aromatic series (1). The phenols are hydroxy (HO) derivatives; carbolic acid is hydroxy-benzene; cresol is hydroxy-toluene; naphthol is hydroxy-naphthalene. The entrance of this hydroxy nucleus renders the two naphthols, alpha and beta, more irritating in their effect than is naphthalene. An increase in the number of hydroxy groups increases toxicity. Thus, pyrogallol, commonly called pyrogallie acid, trihydroxybenzene, is more toxic than phenol, commonly called carbolic acid, which is monohydroxybenzene. The former is used in at least one plant in the United States to produce gallocyanin, but no case of poisoning has as yet been reported here, although such cases are known to have occurred in Germany. Theoretically, phenol or hydroxybenzene should be more toxic than benzene, but as a matter of fact its use in industry is attended with nothing more serious than burns, except in very rare instances in which an accident has caused an overwhelming exposure.

The entrance of the nitroso group (NO) and the nitro group (NO_2) increase toxicity always, whether they enter the ring or a side chain, but it is not necessarily true that an increasing number of NO_2 groups increases toxicity. For instance, the French experience during the war when they used nitrophenols for explosives, showed that picric acid, trinitrophenol, was not nearly so poisonous as one of the dinitrophenols.

Reduction of the NO_2 group to NH_2 , as in changing mononitrobenzene to anilin, mononitrotoluene to toluidin, lessens toxicity, and when these amido compounds are sulphonated they are apparently rendered harmless. The entrance of the sulphonic group (SO_2HO) into any benzene derivative removes its toxicity, as is seen also in the sulphonation of phenol. The entrance of COOH may have the same effect. Nitrobenzoic acid is harmless, although nitrobenzene is very poisonous. The acetyl group (COCH_3) makes acetanilin less poisonous than anilin, and the same is true of the introduction of an alkyl group such as methyl (CH_3), for dimethylanilin is less poisonous than anilin.

Chlorin entering an aromatic compound changes it very little, and certainly does not increase its toxicity, for chlorbenzene seems

to be less toxic than benzene. There is no rule as to the toxicity of different isomers, but usually, according to Fraenkel (1), the para position is more toxic than the ortho. Practically, paratoluidin seems to cause more trouble than ortho, and paranitranilin more trouble than meta, but animal experiments made by Lewis (2) showed that for rabbits metanitrilanilin was more toxic than para. Among the nitrochlorbenzenes, the ortho isomer seems to be the most toxic, next para, and last meta. Usually paraphenyldiamin is regarded as worse than meta, but some dye workers believe the reverse to be true.

Hydroxy Compounds.—Phenol and the two naphthols, alpha and beta, are the only ones of this group which are of importance industrially. None of them gives rise to much trouble, in spite of their decidedly dangerous nature.* They are readily and easily absorbed from any surface, including the unbroken skin, and within the body they are partly oxidized, partly excreted in the urine in combination with sulphuric and glycuronic acids and also unchanged. The urine of phenol poisoning is dark or "smoky." The symptoms caused by the absorption of *phenol* through the skin—the only form in which industrial poisoning occurs—come on rapidly. In severe cases there is great muscular weakness, then loss of consciousness and death from respiratory failure, sometimes preceded by muscular twitchings or convulsions. Less severe poisoning causes headache, dizziness, some excitement and mild delirium, pallor, clammy sweat, irregular respirations and a small pulse (3).

A fatal case was reported to me by the late Dr. T. F. Harrington of the Massachusetts State Board of Labor, of a young chemist who stepped into a pool of phenol waste and soaked his leg in it. Soon after he began to complain of ringing in the ears, dyspnea and dizziness. Then he became dazed, excited and almost hysterical. He was allowed to leave the building in this condition, but evidently he soon lost consciousness, for the next morning he was found dead on the road. The leg was then greenish black up to the knee.

Two other fatal cases of industrial phenol poisoning came also from the accidental soaking of the clothing with this liquid. They were reported to me by Dr. F. G. Patterson, formerly Medical Director of the Pennsylvania Department of Labor. The first was that of a workman who was unscrewing a cap on a phenol drum when some of the contents splashed out over him. A fellow workman immediately turned a hose of running water on him but, according to his statement, the man "became limp almost at once," collapsed, and was dead when the doctor reached him. The second

* This is because in the absence of an accident there is no contact with phenol on the part of the workmen. Splashing drops over the skin is a possible risk, and most factories keep a supply of alcohol near at hand so that the phenol may be washed off immediately.

case was the result of carelessness on the part of a man who had charge of blowing weak phenol into a measuring tank. Without looking to see whether a former charge had been removed from the tank, he blew in another charge. His fellow workman saw the tank overflowing, went up to shut the water off, and got his clothes saturated with 10 per cent phenol. He seemed to be all right, but was sent to the medical department for treatment and when he reached there fell unconscious and died.

The physiological action of the naphthols is similar to that of phenol, and there is also a destructive action on the blood and an injurious effect on the kidney (3). Acute nephritis, even hemorrhagic, has followed the medicinal application of naphthol to the skin. *Alpha-naphthol* is said to be more toxic than beta. The use of *beta-naphthol* in industry seems to be almost without danger, except from irritation to the skin. In plants where beta naphthol is produced the steam is said to be irritating as well as the dust, but in these same departments caustic soda gives more trouble than naphthol.

Nitro and Amido Compounds.—Poisoning from the nitro and amido derivatives produces in general much the same clinical picture, differing in some details and with a few striking exceptions. According to Curschmann (4), there is an important difference between the nitro and amido compounds, in that the latter are simply blood poisons and all of the symptoms produced by them may be referred to their action on the blood, while the nitro compounds have in addition a direct action on the central nervous system. That this is true, with regard to the nitro compounds, is undisputed, but Heubner (5) believes that it is true of the amido derivatives of benzene as well as of the nitro. Heubner succeeded, in his experiments on rabbits, in producing a narcotic effect, with collapse and paralysis, before blood changes had had time to take place, and he believes that not only nitrobenzene, but anilin and phenol, exert a direct action on the lower centers, those of respiration, vasomotor control, and heat regulation.

In a light case of poisoning from one of these aromatic compounds, the face flushes, the man experiences a sense of fullness and throbbing in the head, burning in the throat, tightness in the chest, and then a violent throbbing headache may come on with dizziness, roaring in the ears, and some disturbance of sight. The flushed face now becomes livid, with bluish lips and tongue, and there is a sensation of weakness in the knees, a staggering gait. If prompt treatment is given; that is, if the man is removed from all contact with the poison, which in practice usually means having him strip off his clothes and take a full bath, the attack may last only a few hours, and the man is able to return to work on the following day. But even in so mild a case as this the bluish color of the lips and

tongue may persist for several days. In severer cases, the color of the face is gray-blue, the lips and tongue are more deeply cyanosed, the muscles tremble, the man staggers and feels as if his knees were caving in. He is nauseated and may vomit and complains of cramps in the abdomen and of extreme weakness. Sometimes, usually a few hours after the onset of the attack, consciousness is lost. The respiration is shallow and quick; the pulse is small, fluttering, irregular, and enormously accelerated; the skin is cold, and the blood pressure is usually low. If coma persists, the respiration and pulse grow slower and slower, there is involuntary defecation and urination, and convulsions usually come on just before death. It is a characteristic feature of all these poisons that the attack seldom takes place while the man is at work, but almost always while he is on his way home, or even some hours later.

Many studies have been made of the blood in poisoning from benzene derivatives, and the changes in acute intoxication seem to occur in the following order. Methemoglobin is formed early in the course of intoxication, and probably coincidentally with it is a destruction of red blood cells. (Curschmann (4), Lehmann (6), Mohr (7).) The blood count and the hemoglobin fall. Microscopic examination shows that the red cells are altered in size, shape, and staining properties. The cells are pale, and there is some fragmentation and polychromatophilia. Early in the attack the blood becomes chocolate colored and thicker than normal, and spectroscopic examination may reveal lines which are said to be those of methemoglobin (Mohr), or rather, lines situated between the methemoglobin and the oxyhemoglobin, and therefore not quite typical (Price-Jones and Boycott (8), Brat (9).) If, however, the spectroscopic test is not made till later in the attack, it is usually impossible to detect these lines. Indeed, Curschmann says that by the time cyanosis is fully developed methemoglobin can no longer be demonstrated.

The evidence of the destruction of red corpuscles is succeeded in a few days, from the second to the fifth, by evidence of active regeneration, and the blood picture then may be very much like that of pernicious anemia, with variations in staining and in size and with the appearance of stippled cells and nucleated cells. The changes in the white cells are not so characteristic, but during an acute attack there is usually a polymorphonuclear leucocytosis. Later, as also in chronic poisoning, there is a lessened number of these cells and a relative increase of lymphocytes (Hudson (10)). In the slower forms of poisoning, the destruction of red cells acts as a stimulus to further cell production on the part of the bone marrow, and an increased red cell count may be found. Malden (11) examined the blood of 13 men employed in an English factory where anilin and nitrobenzene were made. Six of the 13 had a

high red cell count with a low hemoglobin, and many imperfectly developed red cells. Loss of hemoglobin ran from 5 to 50 per cent. The cells showed great variations in size, the large predominating, but more noteworthy was the appearance of stippled cells, which Malden considers quite as characteristic of the early stages of anilin poisoning as it is of lead poisoning. Malden summarizes the changes in the blood caused by small repeated doses of anilin, thus: Red cells increased in number with loss of hemoglobin; low color index; degeneration and imperfect regeneration of red cells; increase of lymphocytes, decrease of polymorphonuclear leucocytes.

Very varying results are reported from the analysis of the urine in cases of acute poisoning. Hay (12) produced in himself symptoms of intoxication with marked cyanosis, but his urine showed no abnormality. Sugar and casts are commonly absent in the urine, although there are occasional instances of reduction of Fehling's solution. Albumin is usually not found, except perhaps a trace, in acute intoxication of moderate degree, even when the urine is a dark brown color. This brown color is very common and is often the first warning the workman has that he is beginning to experience the effects of the poison. A chemist who once had had a severe attack of anilin poisoning from drawing a quantity into his mouth while siphoning, told me that always after that if he came in contact with anilin he would notice this change in the color of his urine, although he might feel no subjective symptoms at all.

In severe poisoning the urine may be a dark brown or the color of port wine, or a smoky red, and in such cases methemoglobin or unchanged hemoglobin or blood pigment, bile pigment, hematoporphyrin may be detected. Albumin can sometimes be demonstrated, but not always, even in severe cases (Mohr). Some observers insist that bile pigment is never found in the urine; others, that bilirubin can be detected in the majority of cases. Mohr found hydrobilirubin frequently after dinitrobenzene and chlorbenzene poisoning.

No thorough study has as yet been made of the reduction of Fehling's solution, although the occurrence of this phenomenon is reported fairly frequently. Six such cases were described in a personal communication by Dr. Kessler, of Marcus Hook, in men who had been working with dinitrobenzene and anilin.* Their urine was dark brown, contained bile pigment, and had reducing properties. A seventh case was one of fairly severe poisoning from mononitrobenzene. Dr. Sutherland, of the Du Pont Company, who has some 1200 men under his care, says that he finds not infrequently urines reducing Fehling's in men who show signs of poisoning from nitro or amido compounds. According to von Jaksch (13), a substance which reduces copper sulphate and is also lævo-rotatory was found in

* See Industrial Poisoning in Making Coal-Tar, Dyes and Dye Intermediates. Bull. 280, U. S. Bureau of Labor Statistics, April, 1921.

the urine of a man suffering from nitrobenzene poisoning. This urine smelt strongly of oil of mirbane, and contained a trace of sugar and an increase of ammonia and acetone.

Neubauer (14) says that in severe anilin poisoning, anilin may be found unchanged in the urine, but this is rare. Usually it is changed by oxidation and conjugation to para-amidophenol-sulphuric ester. Nitrobenzene and the nitranilins are also excreted as para-amidophenol, while the reduction product of dinitrophenol, which appears in the urine after poisoning from this substance, is amido-2-nitro-4-phenol.

P. A. Davis (15) of Akron examined over one hundred urines of men in all stages of anilin poisoning, from the early, acute, to the persistent, chronic. He summarizes his findings as follows: specific gravity, 1005 to 1030; reaction usually acid; a large amount of uric acid being present; albumin negative except in extreme anemia; tests for anilin, anilin radicals, phenol, acetone, negative; diacetic acid positive only in severe cases. Nearly all showed traces of hematin if 24 hour specimens were evaporated. Microscopically, there were large quantities of uric acid crystals, urates and oxalates. One specimen had diacetic acid with a trace of sugar, two had involvement of the bladder which improved on change of work and on treatment.

In the early years of the present century the physicians attached to the great color works at Hoechst noticed that workmen in this plant were to an unusual degree victims of tumors of the bladder, sometimes cancerous, sometimes benign. In 1904 they began to ask information from 18 other German dye works concerning the occurrence of bladder tumors and of inflammation of the bladder, cystitis; and the responses to these inquiries brought to light 38 cases, 18 of which were fatal. This report attracted great attention and was followed by others from time to time until, in 1920, the number of known instances of bladder tumor in German dye works reached 177.

At a meeting of industrial physicians in Germany in 1913 Leuenberger (16) spoke on this subject, pointed out the fact that it was undoubtedly an amido, not a nitro body, which must be held responsible for bladder tumor formation, and urged the physicians attached to dye works to tabulate their cases and to discover which were the dangerous departments and what was the compound eliminated in the urine that acted as an irritant to the bladder. The answers to these questions are now appearing in the *Zentralblatt für Gewerbehygiene*.

Industrial poisoning from these compounds, especially from the amido compounds, is rarely fatal. I have records of two cases of fatal poisoning from absorption of nitrobenzene which was spilled on the clothes, and also of two deaths from anilin poisoning, but all of these occurred some years ago when the mode of absorption

of the poisons in question was not understood and prompt measures for thoroughly cleansing the skin were not taken. Death is preceded by coma, increasing paralysis of the heart and respiration, convulsions, and usually by edema of the lungs. Usually there are no characteristic changes in the organs, except in the case of a few compounds, such, for instance, as trinitrotoluene, which during the war caused a number of cases of very characteristic acute yellow atrophy of the liver. The usual findings consist of slight degenerative changes in liver, heart, and kidneys, sometimes of pneumonia or edema of the lungs, or of hemorrhages into the lungs and stomach and intestines.

The benzene derivatives may be inhaled as fumes or fine dust, but the most important mode of entrance into the body is through the skin. Hay (12) experimented on himself, applying to the skin 0.1 gm. of dinitrobenzene in ointment. A few hours afterwards his lips turned a vivid blue, his skin a leaden color; his pulse was 120 with high tension; and there was a sense of fullness and throbbing in his head. Curschmann produced fatal poisoning in cats by rubbing a few grams of paranitranilin on the skin, and the same result was obtained with phenylendiamin. Observations made on an extensive scale in British munition works during the war showed that contact with such substances as trinitrotoluene and tetryl was not only the chief cause of poisoning but was responsible for all the more serious cases (17). This was confirmed by observations made in American munition plants and American dye works (18, 19, 20). Nevertheless, fumes, especially when mixed with steam, gave rise to unmistakable absorption of TNT, and several instances have been reported to me of undoubted fume poisoning from anilin and other compounds in dye works. For instance, a case of poisoning occurred on the second story of an anilin reduction building from the fumes which passed through the cracks in the wooden floor. The reduction apparatus was very defective and it was often necessary to open up the reducers and to empty them, during which time anilin fumes would escape. In another plant, a man who did not come in contact with anilin at all but worked a machine like a cream separator for separating anilin from water, was taken ill and was under treatment for eight days. The installation of a suction fan to draw away the fumes made it possible for him to go back to his work with no further trouble.

From still another plant came the history of a man who was sent to repair pipes in the ceiling above a reducer where monochloranilin was being made from nitrochlorbenzene. Reduction was over and fumes were rising from the open steaming reducer. After 45 minutes the man was overcome by the fumes and had to be carried down. He was dangerously ill for several days and could not return to work for some weeks. Cases of fume poisoning also occur among

men engaged in centrifuging (called "wringing" or "spinning") mixed toluidins to separate the para crystals from the oily ortho. Even when the centrifuges are out of doors very heavy fumes are given off during the process, and it seems that severe poisoning may occur without any direct contact.

Although the description given above is typical of this group of poisons they differ from one another more or less with regard to the prominence of certain symptoms, the degree of toxicity and, in at least one instance (dinitrophenol 1-2-4), there is a decided divergence from the usual type.

The Nitro Compounds.—Mononitrobenzene and meta-dinitrobenzene are very important dye intermediates, and the latter is also one of the most important of the high explosives. *Mononitrobenzene*, known as oil of mirbane, is a yellow, oily fluid smelling like oil of bitter almonds, insoluble in water, but readily soluble in fats. It passes easily through the skin and when spilled or splashed on the skin gives rise to rapid severe intoxication, the blood turning chocolate-colored and the urine dark within a few hours after even a slight accident of this sort. If the clothing is soaked with nitrobenzene, the resulting collapse may be very sudden and severe.

There is the history of a fatal case of nitrobenzene intoxication in the records of the Massachusetts General Hospital for July, 1916. The patient, an elderly man employed in a soap factory, was carrying a five-gallon can of oil of mirbane, some of which he seems to have spilled on his trousers. He suddenly staggered and then collapsed, spilling more of the fluid on himself. It is evident from the record that his mirbane-soaked clothing was not removed, but that he was sent to the hospital as he was, practically in a poultice of nitrobenzene. When he reached there he was unconscious, respirations were slow and irregular, his skin was of a dark gray-blue color, his pupils were small, irregular, and did not react to light. The heart, however, was regular with good action until just before death which occurred an hour after he reached the hospital, preceded by increasing respiratory failure. Some blood was withdrawn from the vein of the arm before death and it was chocolate-colored. A similar case of profound cyanosis and collapse, but not ending in death, occurred in a man who was using a brass polishing mixture which contained nitrobenzene, and who spilled it on his overalls and went on working till he suddenly collapsed.

Dinitrobenzene (meta) is a solid which volatilizes slightly at room temperature. By general agreement it is pronounced to be the most troublesome compound that is used in coal-tar dye manufacture. This does not mean that it is the most toxic of the intermediates, for it is not, but that the requirements of manufacture are such that men are necessarily brought in contact with it in such a way as to

make it difficult to protect them. A chronic form of dinitrobenzene poisoning has been described by the British and the Germans, both of whom have had ample opportunity to observe it among the workers in roburite, a mixture of dinitrobenzene and ammonium nitrate much used before the war, and in German munition plants where dinitrobenzene was the chief explosive used during the war. Prosser White (21) describes a severe form of anemia in dinitrobenzene workers, with dusky yellow skin, jaundiced sclera, an appearance of partial asphyxia, wasted muscles, dulled sensibility, partial paralysis of the hand, defective vision.

German articles, appearing since the war, emphasize the injurious action of dinitrobenzene on the optic nerve and on the auditory nerve. Cords (22) describes four varieties of optic nerve injury ranging from light temporary disturbances to the most severe progressive disorders. The cases in the third group were most numerous. Here was found a more or less pronounced papillitis, followed by a temporal paling of the optic disk. In all these was an advanced central scotoma with loss of color sense for red and green, and frequently complete loss of color sense. There was often pronounced contraction of the pupils with inactivity toward light and accommodation. (See also Reis (23).)

The reports of the German factory inspectors for the war years show that the principal explosive used was dinitrobenzene and that the susceptibility to poisoning from this compound is practically universal. In Bavaria from 1915 to the end of the war there were fully 1000 cases of DNB poisoning and many of the victims had from two to five attacks. The proportion of cases was greater among women than among men, and the proportion for both sexes increased with the tightening of the food blockade. In 1916 the rate was 66 per cent for women, 56.7 per cent for men; in 1918, 119 per cent for women, 100.1 per cent for men. Apparently there were about 113 deaths from DNB poisoning. The British record for TNT is 96 deaths.

In American dye works DNB is often the only substance that causes real alarm. There is much more exhaustion, depression of the heart, than in poisoning from anilin, and the effects of an acute attack last much longer, dragging on sometimes for days or weeks, while in anilin poisoning a man usually recovers in 48 hours. The anemia of DNB poisoning may be profound and persistent. Severe poisoning from a large dose is always the result of an accident or follows some unusual piece of work, such as tearing out bricks and rafters in an old room once used for the production of DNB. Sixteen men engaged on this work were poisoned, several of them remaining unconscious for six or eight hours, and one having convulsions at intervals for twelve hours.

It is not only in the production of DNB, but in its use as an

intermediate, especially for reduction to metaphenyldiamin and to metanitrilanin, that the danger occurs. Sometimes molten DNB is run out into open pans, and when it is caked men chop up the cake and shovel the fragments into trucks. In one plant in which this method was used, it was found that no less than 50 per cent of all the sickness was among the DNB men, although they numbered only 24 in a force of 1500. In consequence, this method has been largely abandoned and the hot DNB is now usually run out to meet a stream of cold water which granulates it or pellets it. However, shoveling and dumping the pelleted DNB and conveying it in trucks causes poisoning; for fumes are given off and it is almost impossible to avoid skin contact. A history of 27 cases of DNB poisoning in men engaged in such work showed that the duration of incapacity was from one to 12 days.

The nitrotoluenes, ortho and para mononitrotoluene, are used to produce by reduction the important intermediates, ortho and para toluidin. During the war dinitrotoluene was produced at a stage in the manufacture of TNT, and in the dye industry it is used for the production of toluyldiamin. None of these is so toxic as the corresponding benzene derivatives: they act more slowly, and many men can handle them with seeming impunity. Their pathology and symptoms, however, are the same. The effects of trinitrotoluene were closely studied during the war and it was found to be a poison with slow action to which about one-third of those exposed were susceptible. Its action was chiefly on the bone marrow, causing a great destruction of red blood cells and a resulting hematogenous jaundice. There were 360 notified cases of toxic jaundice from TNT poisoning among the British munition workers, with 96 deaths. Much less common was an aplastic anemia of extreme type without typical degeneration of the liver. Both forms occurred also in American munition works. Trinitrotoluene is not used in dye manufacture,* but the literature with regard to it is of great value because it enables us to picture the action of similar compounds which have not been tested on human beings so thoroughly as has TNT.

The same thing is true of one of the dinitrophenols which is not in itself important since it is used only to a limited extent in dye manufacture, but, like TNT, its physiological action was tested on great numbers of human beings during the war, and it is safe to suppose that the discoveries made with regard to it may prove to apply to other nitro derivatives of benzene. Before the war *dinitrophenol* 1-2-4 was not known to differ in any way from the other

* I have been told that a peace-time use for TNT is in making "Cordu," a fuse for dynamite, and that "TNT oil" is added to some kinds of dynamite. This oil is removed by wringing from the products of the first stage of nitration of toluene and it has the odor of nitrobenzene and produces serious systemic poisoning.

isomeric forms of this compound, but its manufacture on a large scale for the favorite explosive of the French, *mélinite*, a mixture of picric acid and DNP, revealed a very peculiar and characteristic toxic action on men. Perkins (24) says that acute intoxication comes on suddenly, with a sensation of extreme weariness in the limbs, of painful constriction at the base of the chest, a burning thirst, abundant sweat, and an agitation and anxiety which is quite characteristic. Other very characteristic signs are a dyspnea with especially difficult inspiration, and scanty urine containing a reduction product of dinitrophenol. In severer cases death may take place in a few hours, after a rise of temperature to 104° F. or over, abundant sweats, intense thirst, contraction of the pupils, and sometimes colic and diarrhea. Excitement and terror are followed by coma, convulsions, and death. Temperatures as high as 109.4° F. have been recorded, and in some cases there was a rise of several degrees after death. Autopsy revealed no characteristic lesions.

The French experimenters found that the action of DNP 1-2-4 is highly specific, quite different from the action of the mononitrophenols, except para, which produces similar results, but only in heavy doses and for a transient period. The same thing is true of the 1-3-4 isomer of DNP. The other isomers resemble the nitro compounds in general, causing formation of methemoglobin. The toxic action of DNP 1-2-4 consists in the production of an increased cellular combustion, oxidation, which has no relation to muscular work nor to any action on any special organ nor to a stimulation of nerve centers, for it occurs even in cold-blooded animals. The symptoms are explained as showing an exaggeration of the heat radiation activities caused by the progressive elevation of the temperature, which, in animals, may rise to 113° F. at death.

There were four deaths during the war in the two American factories which manufactured *mélinite* for the French. Three men who were handling dry DNP died within 24 hours after the first symptoms occurred. From the meager report obtainable it seemed that these cases were like those described by the French. The fourth died after an illness lasting several days, which was apparently the typical toxic jaundice as seen in TNT workers. It is possible that in this factory the DNP handled was not the 1-2-4 isomer. Leymann (25), in 1902, described three cases of sudden and severe poisoning which developed in a dye works from the dinitrophenol used in making sulphur black.

The *nitrochlorbenzenes* are used as intermediates for the production of sulphur dyes, especially sulphur black. They are volatile and very toxic, but it is their irritating action on the skin which attracts the most attention and which probably protects the men from severe general poisoning. *Dinitrochlorbenzene*, used in the manufacture of sulphur blacks, has probably caused more dermatitis

than any other compound used in coal-tar dye manufacture. In one Brooklyn plant, every man employed was more or less affected in this way, and during the summer months the place had to close down for lack of labor. One of the men described to me the course of the disease, as follows: it begins with itching behind the knees and at the bend of the elbow and along the inner surface of the thighs, then little red points appear over these areas enlarging and coalescing to form a swollen mass which itches and burns unbearably and which is relieved only by prolonged soaking in alkaline water. Sometimes the face is involved and the eyes swollen shut.

Of the three isomers of nitranilin, two are important—meta and para. Kobert (26) and Rambousek (27) both think that paranitranilin is more toxic than meta. Gibbs and Hare (28) confirmed this and find ortho more toxic than meta, but Lewis (2), experimenting on animals in H. G. Wells' laboratory, found meta more toxic than para. Both, according to Gibbs and Hare, cause formation of methemoglobin and laming of the central nervous system and of the heart.

Paranitranilin is the more important of the two in dye manufacture, being used not only as an intermediate for sulphur dyes and for azo dyes, but also with beta naphthol for the production on the fabric of a bright red dye called para red. The most conspicuous action is on the skin, for it causes a very distressing, burning, itching, eruption, but it is also capable of producing serious and even fatal systemic poisoning. Bachfeld (29) reported nine cases, four of which were serious with scanty and very painful micturition, but with no blood or albumin in the urine. A fatal case was reported from the German dye works at Hoechst in a man who had been working for five hours in paranitranilin dust. Another occurred in an American color works. This was in a white man of 27 years who had been employed for only twelve days in the paranitranilin department. He is said to have been poisoned by dust which resulted from an accident in the drying room, perhaps in tipping over a tray of the powder. The foreman sent him at once to the bath house and he took a bath and remained there for about an hour. Then he went to the works doctor, but after he had been in the waiting room about 20 minutes he lost consciousness and although given stimulants and artificial respiration by means of a lung motor, he died, about two and a half hours after the accident.

Metanitranilin is made from dinitrobenzene by reduction, and poisoning which occurs in such a department may be due to the DNB. I have one instance, however, of a clear case of metanitranilin poisoning in a young workman who was sent to clean out a tub in which metanitranilin had been "processed." Soon afterwards he complained of acute frontal headache, then he vomited, and then

fainted away. He was taken to the hospital and the record reads "vomiting, fainting attacks, headache, rapid heart, very profound cyanosis, with lips and mucous membranes almost black." A similar case is in the records of the New York Department of Labor. The man was sent to clean out a munjer in which metanitrilanilin had been made. He worked off and on from nine in the evening until midnight, when he went off for half an hour for supper, and when he came back he told the foreman that he felt faint and sick at his stomach, but nevertheless he was told to go back to work. At half past four in the morning he was found lying on the floor unconscious and was taken to the hospital. He was deeply cyanosed, respirations were rapid and shallow, pulse was rapid and of poor quality. Eight ounces of venous blood were removed; the color was dark and coagulated slowly. The man did not regain consciousness till 6:30 in the evening and his convalescence was very slow.*

Amido Compounds.—The symptoms set up by the amido derivatives of the benzene ring are less serious than those caused by bodies which contain the NO or NO₂ group, although the cyanosis is deeper. A case of dinitrobenzene poisoning does not present as alarming an appearance as one of anilin poisoning, but the involvement of the central nervous system, the changes in pulse, respiration, and body temperature, are much more grave; convalescence is also slower. Usually a case of anilin poisoning does not incapacitate a man for more than a day or two, although British physicians hold that he should not be allowed to return to work if his hemoglobin is much below normal. But after dinitrobenzene poisoning, a workman is likely to be ill for a fortnight or more.

The earliest cases of *anilin* poisoning in American literature are, so far as I can discover, two reported by Apfelbach (30) of Chicago in 1913. These men were referred to him by factory inspectors, not because they complained of illness, but because of the lividity of their color. Lips and tongue were a deep blue, but the only discomfort the men experienced was slight headache, dizziness and difficulty in swallowing. The first was a press feeder in a printing shop who had been using a new non-inflammable roller wash to clean the ink off press rollers and this proved to contain anilin. The other was mixing alpha-naphthylamin in an open chaser in a paint and color works. Both had methemoglobin in the blood, as shown by spectroscopy.

The next cases were Birge's (31) published in 1914. Two men

* Various nitroso compounds are used as dye intermediates and also used in rubber compounding. They seem always to be irritating to the skin and "nitroso itch" is a common expression in plants making intermediates. The committee appointed by the American Chemical Society to investigate the newer organic accelerators used in rubber compounding reported that para-nitroso-dimethylanilin was productive of trade eczema.

were using anilin black paint, applying it with a brush and then washing the surface with hot suds, work which naturally encouraged skin absorption. They were seized with nausea and general weakness, palpitation of the heart, then violent headache and vomiting, the skin was very pale, the lips blue and they passed dark-colored urine. In 1915, Hayhurst in the course of a survey of the health hazards of Ohio industry found many cases of anilin poisoning in the large rubber centers, where it had recently been introduced as an accelerator of vulcanization and, after the outbreak of the war shut off the German supply, the production of anilin also had begun. R. V. Luce of Akron and I (32) made a study of anilin poisoning in that rubber city in 1916, and found that the condition was fairly common, the victims being known as "the blue boys," from the color of lips and face. In 1917 Lintz (33) described a case which came under his care at the Brooklyn Jewish Hospital. There was marked cyanosis, great restlessness and pulmonary edema, which subsided under venesection, projectile vomiting, involuntary micturition and expulsion of dark fluid from the rectum. The color of the blood was very dark. The systolic pressure was down to 100, the diastolic was 80. By the fifth day the man was discharged entirely recovered.

Newton (34), in 1920, described four cases of anilin poisoning and one of mixed benzene and anilin, in which, added to the symptoms typical of anilin, there was a benzene leucopenia. The white count fell from 10,600 when the poisoning began, to 1,440 some 16 hours later, and then rose to 6,640 after 72 hours. The four cases of anilin poisoning were in employees of an anilin department. One was working inside an anilin-reducing apparatus, the second washed some clothes with anilin, the third and fourth poured anilin into a receptacle and breathed the fumes. The first case is the most interesting. This man, 49 years old, climbed into a reducer on June 26th to clean it out by flushing with a hose. In a short time he began to feel dizzy and nauseated and he had a "warm, sweet taste" in his mouth. He climbed out at once and went to the hospital where he did not lose consciousness but was overcome by mental confusion and bodily weakness. Newton saw him after an hour, in collapse, intensely cyanosed, complaining of chilliness, although his temperature was 101° F. His pulse was weak, dicrotic, 110; the systolic blood pressure was 110, diastolic, 60, but after a hypodermic injection of camphorated oil it rose to 130 and 85. The blood was chocolate colored and flowed freely, the red cells numbered 3,500,000, whites 10,600, hemoglobin 95 per cent. There was strangury at first and when urine was obtained it was dark, sp. g. 1020, acid, negative for sugar, albumin and bile. On June 30th he was still cyanosed and complaining of headache and the blood count had fallen half a million; the pressure was 115 systolic

and 60 diastolic. The cyanosis was still evident on July 7th but by the 13th it had disappeared and he could be discharged although he still was somewhat nervous and sleepless.

This was a case of moderate severity. More serious poisoning occurred in an Akron man engaged in experiments in connection with rubber compounding, work which involved exposure to contact and fumes (32). One morning he went to work at seven feeling perfectly well in every way, but after about an hour and forty minutes he began to have throbbing in the head and increasing nausea which he attributed to the July weather and to the poorly ventilated room. He next noticed palpitation of the heart, and then a violent headache came on, increasing in intensity and accompanied by vertigo. As he said, "I felt as if I had been standing on my head for a long time and every ounce of blood in my body had rushed to my brain." The dizziness increased, and about 45 minutes after the onset of the first symptoms he lost consciousness. He was hurried to the hospital where oxygen and heart stimulants were administered, but apparently with little effect; for the cyanosis persisted, the heart action was very feeble for more than 16 hours, and he did not regain consciousness till the following morning, a period of about 22 hours. A catheterized specimen of urine obtained on admission showed no abnormality, but a specimen 18 hours later was smoky, with specific gravity 1022, a trace of albumin, no sugar, but hemoglobin was demonstrated by the Heller test and the Schönbein-Almen turpentine-guaiac test. This hemoglobinuria persisted for five days. A blood examination made on entrance gave normal findings in all respects except for a slight eosinophilia, but four days later there were stippled red cells and some irregularity in the size and shape of the red cells. The hemoglobin was 75 per cent (Sahli). The patient suffered from severe headache for five days and complained of weakness and exhaustion some two weeks longer, after which he slowly improved.

Friedländer (35) reported from the Municipal Insane Hospital in Frankfort a case of acute maniacal delirium in a man who had loosed a rubber pipe leading into an anilin receptacle and had received a splash in the face and mouth, swallowing about a mouthful. About four hours later he became delirious and was brought to the hospital in a strait jacket and deeply cyanosed. The next day he was rational but excited, and by the third day the cyanosis had cleared up, but he was still restless and irritable and his heart was still weak and rapid. By the fourth day his mentality was normal. A somewhat similar history was related to me in an American dye works. The man was a pipe fitter making repairs in the ceiling over the anilin reducers. Suddenly he became maniacal and ran amuck over the plant, and it was six hours before he came to himself. The foreman thought this was an instance of fume poisoning, but

it seemed to me possible that the steam from the reducers carrying anilin with it had gradually soaked the ceiling and in working there the man's hands had become saturated with anilin.

Chronic anilinism was described by Hirt as characterized by disturbances of sensibility and of the motor nerves, inertia, headache, digestive disorders, skin eruptions, and roaring in the ears. In the early days of rubber compounding with anilin just prior to the war, workmen in Akron who were exposed to anilin were not infrequently treated by their physicians for chronic valvular heart disease with failing compensation, because the cyanosis, the altered pulse, the complaint of palpitation of the heart, breathlessness on exertion, weakness and easy fatigue, and indigestion, all seemed to point to such a diagnosis. A typical case of this sort came to my attention in 1914. The man had worked with anilin for nine months. He complained especially of muscular weakness and fatigue; palpitation of the heart came on when he had any unusual exertion, and almost always at the end of the day's work; and he had frequent headaches while at work, sometimes severe and accompanied by nausea and dizziness. He was never cyanosed, and while examination showed a rapid pulse, 94, there was no abnormality of the heart. His blood examination showed the condition described by Malden (see page 494); namely, a red cell count of 5,400,000, with only 68 per cent hemoglobin.

Davis(15) has seen men in the rubber industry who "seem to acquire a tolerance for anilin, in that they remain cyanotic for years without the development of any apparent serious symptoms. . . . These patients have some blood changes, of course, yet they feel no ill effects except for a slight tired feeling at the end of the day's work. The body attempts to maintain an equilibrium between intake and output of anilin but there is a surplus amount which is absorbed and which causes blood changes that are responsible for the marked cyanotic condition."

It is generally recognized in American anilin plants that long exposure to anilin is likely to make the men irritable, hard to get along with, "grouchy." The foremen say that such men are not really up to a full day's work and if they try to push them it only makes things worse. They are likely to have a poor appetite and complain a good deal of headache. Sometimes eczematous rashes appear, or pustular eruptions, particularly on covered parts of the skin, the scrotum, arm pits, and inguinal regions.

Curschmann (4) lays great stress on a slowly developing form of poisoning, not only from anilin but even more from solid amido compounds. He says that in such cases the earliest sign of chronic poisoning is a loss of hemoglobin, and therefore blood examinations are of great practical importance, because any workman who has lost from 15 to 20 per cent of his hemoglobin is facing the risk

of an acute attack of poisoning and should be temporarily suspended from work. At this stage he may be slightly cyanosed, but typical microscopic changes in the blood are not found till a later stage. He had a case of almost typical neurasthenia and the only thing that pointed to anilin poisoning was the loss of hemoglobin and the rise in blood pressure, which last he considers a valuable diagnostic sign. The average blood pressure (Riva-Rocci) in 100 workmen not exposed to anilin, Curschmann found to be between 110 and 120, but in men intoxicated with anilin it ran from 135 to 165. In cases of pronounced anemia with cyanosis there may be a rise of 40 in pressure, and at the same time the pulse is always slow, down to 48. In these cases the urine is brown and there is slight jaundice.

In the foreign literature there are frequent references to disturbances of vision in the course of anilin poisoning; as, for instance, among the dyers in a Swiss factory as described by Senn (36). This consisted in a loosening of the epithelial covering of the cornea followed by inflammation, cloudiness, and consequent dimness of vision. The men were working over vats of steaming anilin black, containing free anilin, and Senn attributed the trouble to the action of oxidation products of anilin, the quinones, which cause painful smarting of the eyes so that the victim rubs them vigorously and detaches the surface cells, leaving the cornea exposed to further cauterization.

Very few fatalities have occurred from anilin poisoning, and those chiefly in the years before 1917, when its manufacture was still largely experimental in this country. The most recent death of which I have heard took place in a small, poorly managed works in New England. On the afternoon of August 7th, 1922, a workman was overcome by what was said to be anilin poisoning, while making phenyl 1-8 acid. In this process anilin is driven by compressed air from drums to an autoclave, where naphthalene and sulphuric acid are added. The temperature is raised to 160° C. and kept there for some 24 hours, then the mixture is pumped to a still and the remnant of anilin not used in the reaction is distilled off and returned to the drum. The man who suffered from the fumes from this process recovered, but the following night the foreman in charge who was working alone in the room, somehow spilled anilin on his trousers and was found at half past three in the morning in a semi-conscious condition, from which he never recovered.

The *toluidins*, *ortho* and *para*, are considered by some to be more toxic than anilin, although toluene is much less toxic than benzene. Treitenfeld (37) found that they worked very much as anilin does, with the same effect on the central nervous system, but causing rather less cyanosis. Rambousek says that they act like anilin, but produce more injury to the urinary system, more strangury and hematuria than does anilin, and this statement is confirmed by

Kessler of the Anilin Products Co. Gibbs and Hare tested the three isomers, para, ortho, and meta toluidin, on animals and found that all destroy red blood cells, lower the body temperature, and lame the spinal cord. The fatal dose per kilogram of body weight is: for para, 0.1 gm.; for meta, 0.125 gm.; and for ortho, 0.208 gm. Metatoluidin is not used in dye manufacture, and experience in American dye works usually shows that para is more toxic than ortho, although it is crystalline, while ortho is an oily liquid. The toluidins are often said to give more trouble than anilin, but this is not necessarily because they are more poisonous, but rather because no process in connection with anilin, except repairing and cleaning apparatus, necessitates so much exposure to fumes and contact as does the centrifuging or "spinning" of the two toluidins. Friedländer (35) and Stark (38) have both reported cases of severe poisoning with coma, maniacal delirium, and great prostration, following the splashing of toluidin on the skin. In both cases there was scanty, bloody urine passed with agonizing pain.

Very little is written of the action of the *xylydins*, but they are undoubtedly much less poisonous than anilin and toluidin. The diamins are well known poisons. Indeed, *toluylendiamin* has long been regarded as a typical blood poison causing extensive destruction of red blood corpuscles, methemoglobin, severe hematogenous jaundice with destruction of liver cells. (Stadelmann (39), Dragendorff (40).) The two *phenylendiamins*, *meta* and *para*, are very important dye intermediates, and *para* is also used for dyeing furs under the trade name of Ursol. Formerly, before its dangerous nature was discovered, it was used as a hair dye, and according to Knowles (41) was responsible for not only a dermatitis but severe symptoms of nervous disturbance, sleeplessness, dizziness, weakness of the legs, and even epileptiform convulsions, coma and death.* According to Blaschko (42) and also Olson (43), the irritating effect of hair dyes and fur dyes containing paraphenylendiamin is not caused by this compound but by the presence of a mid-product, quinone dichlordiamin, which is much more irritating to the skin. Very interesting reports have been published lately of the occurrence of attacks of bronchial asthma in furriers using Ursol, attacks which resemble anaphylaxis. (See Olson (43).)

Hanzlik (44), however, rejects the theory that anaphylaxis is

* A report was made by a committee appointed by the Rubber Section of the American Chemical Society to inquire into the toxicity of the organic accelerators of vulcanization (see p. 524), and the one which was pronounced most dangerous was para-phenylendiamin. It was said to produce, when inhaled as dust, symptoms of a common cold with sneezing and extreme depression. A large dose causes death with symptoms of ptomaine poisoning. This is the only reference to such an effect which I have seen in the literature. The report of the committee may be found in *The India Rubber World* for 1918, Vol. 59, p. 82.

the basis of the asthmatic symptoms which develop in consequence of exposure to phenylendiamin and its oxidation product, quinonediamin. The irritation is the direct result of the inherent chemical properties of these bodies and is independent of precipitation in the tissues. Hanzlik found that all the phenylendiamins are toxic compounds, *dimethylparaphenylendiamin* being the most so, then *diethyl*, then *paraphenylendiamin* and *metaphenylendiamin* is probably the least so. The diethyl and dimethyl compounds are absorbed through the skin with extraordinary ease, in fact the dose required for this mode of poisoning is no larger than for poisoning by hypodermic injection, a property due to their marked volatility and lipoid solubility. He estimates that about a teaspoonful of dimethyl-p-phenylendiamin held in the palm of the hand would be enough to kill an adult man. The vapors also may cause death.

The two alkyl compounds are very irritating to the skin, the others are not or are very slightly so in animal experiments. All of them stimulate the circulation and respiration, cause fall of body temperature, tremors, increased reflex excitability, convulsions, coma, death. The hypodermic and gastric administration of *paraphenylendiamin* produces in rabbits an edema of the face, nose, conjunctiva and neck, while *meta-phenylendiamin* causes hydrothorax, and therefore it seems probable that the asthma and other respiratory symptoms which have been observed in workers in the fur-dye industry are due to direct irritation and bronchial stimulation and not to anaphylaxis. *Paraphenylendiamin* is used as an intermediate for sulphur dyes; *meta*, as an intermediate for Bismarck brown, Manchester brown, and many azo dyes. It is often looked on as more dangerous than *para*, but this may be because it is made by the reduction of dinitrobenzene, and it is quite possible that this last is responsible for some of the trouble. *Paraphenylendiamin*, on the other hand, is made by the reduction of *para-amidophenol*, which is comparatively non-toxic.

Other compounds belonging to this group are the methyl and ethyl derivatives of anilin, which are distinctly less poisonous than anilin. In the early days of American dye manufacture, 1916, two severe cases of poisoning by *dimethylanilin* were reported to the New York State Department of Labor, but such cases are exceptional. One of them was caused by direct contact with *dimethylanilin*, but the other seems to have been caused by fumes. A man of 22 years had been employed for two weeks on the night shift. One night at half past ten he climbed a ladder to inspect a vat of dye which was said to be crude violet made from *dimethylanilin*, phenol, and other substances. He lifted the lid, breathed the fumes, and fainted, and the doctor who was summoned thought he had fallen into the violet dye, he was so deeply cyanosed. He did not recover consciousness for eight hours, and then he was taken to the hospital

complaining of impaired vision, roaring in the ears, and intense pain in the abdomen. He was in the hospital for seven days.

Anilin hydrochlorid produces exactly the same symptoms as anilin, and there may be a good deal of poisoning in the course of its production, although the work is usually carried on in an open shed to allow the fumes to escape. A fatal case of anilin poisoning reported by White and Sellers (45) at the Brussels Congress of Industrial Hygiene in 1910 was in a man who splashed anilin over himself while making anilin hydrochlorid and died within 24 hours. Price-Jones and Boycott (8) used this compound in their animal experiments and brought about all the blood changes characteristic of anilin. *Sulfanilic acid* is produced in the same way by the use of sulphuric instead of hydrochloric acid. The same risks attend its production, but there is no proof of its toxicity. A very slightly toxic compound is *anthranilic acid* (ortho-amido-benzoic acid) which is used for lake colors and for the pigment, scarlet B, the dye used for two-cent postage stamps. *Benzaldehyd*, or oil of bitter almonds, is, according to Kobert, quite harmless.

More or less severe trade dermatitis is caused by *para-amidophenol*, an important intermediate, especially for sulphur dyes. It is produced by the reduction of paranitranilin, which is much more poisonous. The excretion of both nitro and amido derivatives of benzene from the body is preceded by their reduction to para-amidophenol, which is found in the urine as an alkaline salt of para-amidophenol-ether-sulphuric acid.

Frequent cases of dermatitis are reported from a German *phenylhydrazin* plant among the men who wrap the product in cloths for the filter. An explosion of a distilling kettle full of this compound resulted in the death some days later of one workman and inflammation of the eyes of a large number of others.

Amidoazotoluene, or scarlet red, is derived from orthotoluidin and is used in alizarin color manufacture. It is known to physicians as a stimulant for tissue growth, useful to hasten healing after severe burns. Two cases are recorded of cyanosis, dizziness, headache, slight fever, rapid pulse, and albuminuria after such an application of scarlet red.

The naphthalene derivatives are far less toxic than benzene or toluene derivatives, as would naturally be expected. The naphthols, which bear the same relation to naphthalene as phenol does to benzene, resemble phenol, but are less soluble and less corrosive. *Alpha-naphthol* is more strongly antiseptic than beta and probably more poisonous. The use of *beta-naphthol* in industry, especially in making para reds, seems to give rise to little if any trouble, except for its effect on the skin, and even the fumes are said to be irritating to the skin, but the caustic soda used in producing beta

naphthol is much worse in this respect than the beta-naphthol itself. *Nitroso-beta-naphthol*, formed at one stage in the production of H acid, gives rise to dermatitis, as do all the nitroso compounds; while *dinitro-naphthol*, or Martius yellow or Manchester yellow, has the usual action of a nitro derivative, but is one of the weaker members of the group.

The *naphthylamins*, *alpha* and *beta*, are capable of producing symptoms characteristic of amido compounds, although, according to the testimony of practical men, *alpha* never causes severe poisoning. Beta-naphthylamin seems to be distinctly more toxic, and in one large American plant where there is no trouble at all with the *alpha* compound the men in the crude naphthionic department who come in contact with beta-naphthylamin suffer not only from cyanosis but from frequent micturition, apparently from over-acidity of the urine.

The *pyridins*, used in the making of anthraquinone and in other processes for indanthrene dyes, are said to make the men "dopey," to give them headache, dizziness, dulling of the intelligence. They have also a curious effect on the skin similar to that which has been described in English briquette factories as a result of handling of tarry substances. The skin is raw and sensitive as if from sunburn, and the man suffers most after washing his face and hands and forearms and going out into the open air.

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CHAPTER 35

THE COAL-TAR DYE INDUSTRY

It is impossible to describe the very complicated processes of color manufacture in a work of this sort except so far as it must be done in order to make clear the toxic features connected with each.* Generalizations about the dangers of this industry would necessarily be inaccurate, because not only do the different departments differ a great deal in character, but the various classes of dyes are attended with different dangers. There are, however, certain fundamental chemical processes that are used in dye production, some of which involve well recognized risks, others are usually safe but involve accidental dangers, often perhaps quite unforeseen. These processes follow.

1. *Sulphonation*, or treatment with fuming sulphuric acid. This very common procedure results in the replacement of an H atom by the sulphonic acid group, SO_2HO , which often changes a toxic to a non-toxic body. The troublesome features of sulphonation are the handling of the compound that is to be sulphonated, benzene, anilin, toluidins, etc., and in the possible escape of sulphur dioxide fumes.

2. *Caustic fusion*, or *melting*, or *hydrolyzing*. Usually a sulphonated product is fused with sodium hydrate and the sulphonic group replaced by a hydroxyl, OH, group. In this way benzene-monosulphonic acid yields hydroxy-benzene, or phenol, and naphthalene-monosulphonic acid yields alpha and beta naphthol. The danger here is from the sodium hydroxid, not only from contact with the solid or liquid but from exposure to the steam which carries it. Caustic burns, sometimes very severe, are fairly common in this department, and disastrous accidents sometimes occur from splashing or spilling, or, even worse, from the blowing up of the autoclave used for caustic fusion.

3. *Nitration*. A mixture of nitric and sulphuric acids is used, the latter being added to take up the water liberated in the reaction which would otherwise result in too great a dilution of the nitric acid. The dangers in this process consist in handling the compound which is to be nitrated, in handling the mixed acids, and in exposure to the fumes of nitrogen oxids which are always given off

* For a more detailed description of American and German color manufacture see Bull. 280, U. S. Bureau of Labor Statistics.

when nitric acid is added to these organic substances. It must also be remembered that the product resulting from nitration is more toxic than the original compound. The waste acid from the nitrators is also a source of danger; for it often carries enough of the product of nitration to cause poisoning. In making dinitrobenzene the first waste acid may contain as much as 20 per cent and must be used again and again to recover it.

4. *Reduction.* Acid reduction is carried on with the aid of hydrochloric acid and iron filings. It is used in the production of anilin from nitrobenzene, of ortho and para toluidin from nitrotoluene, and of alpha-naphthylamin from nitronaphthalene. It is also used in the reduction of dinitrobenzene to phenylenediamin, dinitrotoluene to tolylendiamin, etc. Since reduction begins with a nitro compound and ends with an amido compound, it follows that there is in this department a decided risk which is more or less recognized and guarded against in every plant. When the process goes forward normally without any hitch there is little trouble with sickness among the men, although the taking of samples from time to time may give rise to mild poisoning if the sampler spills it on his skin, and in hot heavy weather, especially on the night shift, the fumes which escape from the feed hole may cause enough discomfort to force a man to quit work for that shift, although he is able to return for the next one.

Serious poisoning, however, occurs only when the mechanical arrangements for reduction are faulty. The iron filings fall and cake around the paddles and the reaction has to be interrupted, the manhole opened, and the "sludge" cleaned out for a fresh start. Although this is a rare accident in some plants, it is in others apparently an ordinary occurrence. Under such circumstances, the floor is covered with a wet mass of black iron filings, the anilin water lies about in pools, the men work through the open manhole prodding the caked mass with iron rods and dragging it out with a hoe. Their hands and clothing show the contact with the anilin-laden sludge. In such a place anilin poisoning is looked upon as a serious thing, although in well managed plants only an occasional slight case is seen. Even more dangerous is the reduction of dinitrobenzene to phenylendiamin.

Alkaline reduction is produced by the nascent hydrogen formed when zinc dust and caustic soda are in contact. This is used in the production of benzidin from nitrobenzene, the tolidins from nitrotoluene, and the xylidins from nitroxylene. The second stage in this form of reduction is getting rid of the zinc dust. The method used in British factories and in the smaller factories in the United States is to change it to the soluble chlorid by adding hydrochloric acid and to filter it off. In the larger American plants acid is not used. The zinc dust is separated by passage through

a very fine screen which catches the crystals and lets the dust through. There is one danger in connection with alkaline reduction which is present also, but to a much slighter extent, in acid reduction. This depends upon the possible presence of arsenic in the metal or in the acid, that is, in the iron and hydrochloric acid used for acid reduction, or in the zinc powder and hydrochloric acid used for acidification after alkaline reduction. (See page 228.) Accidental poisoning, serious and even fatal, from this source occurred in the earlier days of German dye manufacture and in recent years in British and American dye works. Fortunately the method used in America for the production of benzidin and tolidin does not carry this risk.

5. *Chlorination.* The introduction of the chlorin atom may take place in the benzene ring or in a side chain, and the resulting product may be highly poisonous or inert. The escape of fumes of hydrochloric acid and of chlorin gas constitute a danger, and these fumes are especially troublesome in the making of anilin hydrochlorid and of nigrosin.

6. *Alkylation.* This consists in the introduction of methyl or ethyl groups into a hydroxy or amido group, as when diethylanilin is made by treating anilin with ethyl alcohol. The more important intermediate, dimethylanilin, may be made by the action of methyl alcohol or methyl chlorid on anilin under heat and pressure. Several cases of poisoning have been reported from such work, sometimes from the methyl alcohol, but more often from the anilin. A much more dangerous method is to use dimethyl sulphate which requires no pressure and is therefore cheaper. This introduces a very toxic compound. (See page 437.) Methyl alcohol is also used in the alkylation of fuchsin to form other colors.

7. *Oxidation.* The substances used as oxidizers are usually inorganic salts, such as sodium bichromate or chlorate or permanganate, manganese dioxid, lead peroxid, with a mineral acid. In making alizarin dyes, the important intermediate is anthraquinone which is produced by oxidizing anthracene with sodium bichromate. Apparently in American dye works no serious trouble is experienced from the use of the chromates, but oxidation may result in the production of poisonous quinones, a danger not generally recognized. In making fuchsin, the oxidizing agent is nitrobenzene, or orthonitrotoluene.

8. *Carboxylation.* This is generally effected by the action of caustic soda and pure carbon dioxid upon a phenol, as a result of which the COOH group is introduced into the ring. For instance, salicylic acid, which is much used in dye making, results from the carboxylation of phenol. This process is not so dangerous as caustic fusion because it does not require nearly so much free alkali, and the resulting compound is less poisonous than the original.

9. *Liming.* Lime or chalk, or sometimes caustic lime, is added

to a sulphonated product to separate one salt from another. For instance, in the production of beta-naphthol the separation of beta-naphthalene-sulphonic acid from the alpha is brought about by adding lime because the lime salt of the alpha acid is very soluble in cold water and that of the beta acid is only slightly so.

10. *Condensation.* This consists in the union of two compounds, or two molecules of the same compound, to form a new one by the loss of water or HCl or H_3N . Sometimes hydrochloric or sulphuric acid is used with phosphorus, zinc, sulphur, or tin to bring about the reaction. There is no special danger involved except from accidental escape of fumes or splashing of the liquid.

11. *Diazotizing and coupling.* An amido compound when treated with nitrous acid, usually produced by sodium nitrite and hydrochloric acid, yields a compound called *diazo*. This is then coupled with an aromatic amine or a phenol to form an azo compound. Although the bodies that are diazotized are toxic, the fact that the reaction of coupling is carried on in the cold lessens very much the danger of both fumes and contact. An instance of the many dyes that are made in this way is chrome brown which is made by diazotizing dinitroamidophenol, usually called picramic acid, and by coupling with beta-naphthol.

The making of intermediates is on the whole attended with more risk of poisoning than the making of finished colors, and the benzene, toluene, and xylene intermediates are much more dangerous than are the naphthalene and anthracene.

The making of azo dyes is probably the safest branch of the color industry, and in a factory which does not make its own intermediates there is very little risk of occupational poisoning. Typically, the work is carried on in one high building with three levels, the coupling tanks into which the intermediates are blown being on the top level, so that whatever fume escapes is taken care of up there and does not contaminate the air on the other levels. Diazotizing is done at about zero, Centigrade.

Anthracene dyes may be produced also without much risk of trouble. The most important of these is alizarin, or synthetic madder. To produce this, anthracene is oxidized, usually with potassium or sodium bichromate, to anthraquinone and this is sulphonated and then fused with caustic soda and chlorate of potash to form alizarin or dioxyanthraquinone. Indanthrene colors involve more risk; for greens and violets are produced by the use of chlorin gas, nitrobenzene, and nitric acid.

Indigo is made in various ways. In two of the three plants which I have visited, formaldehyd and anilin are used, and sodium cyanid is either added or is formed in the course of the reaction. Strong ammonia fumes may be given off at this stage. This reaction is followed by hydrolyzing with caustic potash to form phenyl-

glycin. It is in the filtering, drying and transporting of phenylglycin, which always carries some unchanged anilin, that most of the illness among the workers occurs; for it is a very light and fluffy powder, difficult to transport and to pack. Serious acute and chronic anilism is likely to occur unless unusual precautions are taken. In the third plant, anilin and monochloracetic acid are used to form phenylglycin, and during the process fumes are given off, containing anilin, hydrochloric acid and chlorin. Monochloracetic acid is strongly caustic.

The di- and tri-phenylmethane, dyes are called anilin dyes and toluidin dyes. The intermediates used are derivatives of benzene, toluene, and xylene, and there is probably more typical nitro and amido poisoning in connection with this class of dyes than with any other. The only diphenylmethane color of importance is auramin, in the course of the manufacture of which strong fumes of ammonia, and also of H_2S , may be given off. The triphenylmethane dyes which include the fuchsin series, the malachite green series, and all their many branches, are very important.

Eosins and fluoresceins are closely allied to the above, and are sometimes classified with them, sometimes called pyrone dyes, sometimes resorcin dyes. Chlorin, bromin, and iodine are used in their production, but the gases are held in cylinders and not enough is used to give any trouble.

Nigrosin and indulin are made by melting anilin and nitrobenzene, ferric chlorid, and hydrochloric acid. The last may give off troublesome fumes.

The nitro or nitroso dyes are in themselves poisonous. The best known are picric acid (trinitrophenol), Martius yellow (dinitronaphthol), and aurantia (hexanitrodiphenylamin). The greatest risk of industrial poisoning, however, is in their manufacture, which involves nitration processes.

The making of sulphur dyes may result in the liberation of fumes of sulphuretted hydrogen, and the intermediates used are decidedly toxic. For instance, chlorbenzene is nitrated and the resulting paranitrochlorbenzene crystals must be separated from the ortho liquid. The vapors from this are very toxic. These crystals are saponified to paranitrophenol which is a prolific source of dermatitis unless it is handled with great care. For sulphur black, dinitrochlorbenzene is used, and the production and use of this compound in the early days of American dye manufacture gave rise to so much distressing skin disease as to necessitate changes in method or it would have been impossible to keep the men at work. The danger from fumes of hydrogen sulphid is greatest in connection with sulphur black, and least in making sulphur blue. As a usual thing, an effort is made to burn the H_2S and form a mixture of sulphur oxids, but in one plant powerful suction carries the gas to an iron column where it is absorbed by caustic soda.

The processes involved in dyeing with anilin black and the effect on the workmen were described by Williamson of Manchester, England, as follows: Anilin black dyeing is not a direct process like dyeing with other anilin colors. Although there are several direct anilin black dyes on the market, the only method of producing a satisfactory anilin black is by an indirect method, the dye being actually manufactured on the cloth during the process. This end is attained by the oxidation of an anilin salt by sodium chlorate or sodium bichromate in the presence of some metal compound which acts as an oxygen carrier, such as copper sulphate or a ferric salt.

The One Bath Process (Hot and Cold). This method is used chiefly for yarn dyeing. The goods to be dyed are allowed to stand for about half an hour in a cold bath containing a solution of anilin hydrochlorid and sodium bichromate; the bath is then brought to the boiling point for half an hour, then the material is washed, soaped, sized and dried.

The Oxidation Process. Two liquors are prepared, the anilin liquor which may be made from anilin hydrochlorid but more often prepared on the premises by combining anilin and hydrochloric acid; and the bluestone liquor, chiefly copper sulphate. The liquors are mixed and put into an impregnating machine, a trough with rollers that mangle the fabric, then pass it over drying cylinders to the "ager," a hot closed chamber where oxidation takes place. The chemical processes here are complex and not fully understood, but some vapor of anilin is evolved and it is almost impossible to prevent its escape at the points where the cloth enters and leaves the ager.

The Steam Process. This is also called the prussiate, ferrocyanid, or Prudhomme process. It is used in printing as well as dyeing because, though slower than the oxidation process, it is more under control and the black is said to be more durable. Aging is done in a steam ager, and steam and anilin vapors may escape.

Williamson found only mild forms of anilin poisoning, with pallor, blueness of the lips, ears and nails, occasionally a blue line along the edge of the gums, and tremor and dyspnea. The patients complained of loss of appetite, nausea, dizziness, headache, and a feeling of weakness in the legs. These symptoms were more pronounced in those whose working day was the longest. The blood examination showed a loss of hemoglobin and a lowered red cell count (71 per cent and 4,164,000 were the lowest figures found), but no other changes of more than a very slight degree.

RECORDS OF SICKNESS IN AMERICAN DYE WORKS

Cases of poisoning have occurred in the United States from the following substances used in the making of dyes and dye intermediates:

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Benzene.	Para-amidophenol.
Toluene.	Dinitrophenol 1-2-4.
Mononitrobenzene.	Paraphenylendiamin.
Dinitrobenzene.	Metaphenylendiamin.
Paranitrochlorbenzene.	Nitrosobetanaphthol.
Orthonitrochlorbenzene.	Alphanaphthylamin.
Dinitrochlorbenzene.	Betanaphthylamin.
Anilin.	Benzanthrene.
Paranitranilin.	Anisols.
Metanitranilin.	Quinones.
Dimethylanilin.	Phenylcarbylamin.
Diethylanilin.	Phenylhydroxylamin.
Anilin hydrochlorid.	Solvent naphtha.
Paranitrochloranilin.	Pyridin.
Nitroso dimethylanilin.	Nitric acid and nitrous oxids.
Paranitrotoluene.	Sulphuric acid and sulphur dioxid.
Dinitrotoluene.	Hydrochloric acid and chlorin.
Orthotoluidin.	Hydrogen sulphid.
Paratoluidin.	Hydrogen arsenid.
Paranitrotoluidin.	Monochloracetic acid.
Orthonitrotoluidin.	Sodamid.
Acetylparatoluidin.	Sodium hydroxid.
Benzylchlorid.	Ammonia.
Chlorinated toluene.	Methyl alcohol.
Paranitrophenol.	Phosgene.

Cyanosis from the handling of nigrosin has been reported, but probably should be attributed to anilin. Cases of dermatitis are said to occur among men making azo colors, and the condition is called "azo itch." It is doubtful whether the cause is to be found in the finished colors. It would seem more probable that it should be attributed to one of the nitroso intermediates, because in treating dimethylanilin with sodium nitrite the nitroso compounds of the corresponding bases are formed and these are known to be very irritating. It is possible that in making azo dyes some nitroso might be formed, as, for instance, when the amin to be treated with the nitrite is impure and contains phenols or secondary or tertiary amins.

In an industry so new as the anilin color industry, it is very important to know not only which are the possible dangers which threaten the workmen, but which are really serious and which are only exceptionally serious. I have records from three large American factories which throw some light on this question. In one of these the different processes have been classified according to their danger, so that the examining physician may decide, on the basis of the physical condition of the applicant for work, in which department he can safely be placed. There are three classes of processes:

Class 1 includes operations or processes in which nitro or amido compounds are used and which experience has shown involve risk of poisoning to the workman. Under this classification come the following departments: Naphthionic crudes, dinitrobenzene, the di-

amins, the so-called "anilin dyes"—(rosanilin, magenta, fuchsin, anilin blue, alkali blue)—phenylglycin drying, anthraquinone, pyridin, indanthrene yellow.

Class 2 includes operations or processes involving the handling of nitro or amido compounds, but which are attended with less risk, either because the poisoning set up is less severe, or because the equipment is so arranged that there is no contact with the poisonous substances. In this class come paranitranilin purification, betanaphthylamin, anilin reduction, benzidin manufacture, auramin, and benzanthrene.

Class 3 includes operations which do not involve handling nitro or amido compounds, or in which such compounds are present but no ill effects have thus far resulted from such work. This class is large and includes the ortho and paratoluidin department, sulphonating processes of all kinds, all low-pressure autoclave work, naphthionic purification, picramic acid, benzoic acid, chloracetic acid, salicylic acid, chlorin, hydrochloric acid, chlorbenzene, benzaldehyd, sodium sulphid, nitranisol, eosin, victory green and sulphur black and indigo.

The record of a plant in which about 850 process men are employed and about 400 laboratory men is as follows, for one month of hot summer in 1918:

	Cases
Poisoning from nitro and amido compounds, new cases.....	29
Poisoning from nitro and amido compounds, old cases still under treatment	26
Acid burns of cornea.....	20
Acid burns of cornea with conjunctivitis.....	29
Dermatitis	122
Alkali in eye, inflammation.....	26
Alkali burns	82
Chlorin fumes	1

The improvement that has taken place in this plant of recent years is shown by the record of days lost on account of occupational disease in relation to the output of the plant. There was at first a great deal of trouble in the ortho and paratoluidin area, and for a time the cases of poisoning were very frequent. Then exhaust ventilation was installed to remove fumes not only from the liquids but from the solids also. The men were given rubber boots and gloves and they were strictly watched and sent to the hospital for treatment at once if the slightest sign of illness appeared. The days lost on account of poisoning which in December of 1918 had been 61 for an output of 125,000 pounds, had reached zero in June of 1919, with an output of 340,000 pounds.

For a second plant the records for six months in 1918, from January to July, are available. The number employed at this

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time was about 1600, something over 700 of whom were process men and about 100 engaged in laboratory work. The company considered only cases of acute fume poisoning or of injury to skin or eyes by acids and caustics as "occupational" in character, so in order to get at the amount of illness in the different departments one must look also through the list entitled "non-occupational." This gives the number of cases among 1649 men in six months as follows:

	Cases
Gastro-intestinal diseases	63
Colds, catarrh, coughs, grippe.....	69
Lumbago, rheumatism, etc.....	12
Headache	13
Abscesses, boils, etc.....	27
Skin eruptions	37
Conjunctivitis and sundry eye diseases.....	72
Unclassified	43
Total	336

The different classes of employees suffered in the following proportions during the six months:

Class	Number of employees	Cases of sickness	Per cent sick
Mechanical and yard.....	627	116	18.5
Office force, police, etc.....	200	11	5.5
Laboratory	97	18	18.6
Intermediates	300	85	28.3
Colors	270	73	27.0
Raw materials	146	33	22.6

During the same period a record of accidents was kept, both those involving loss of working time and those needing treatment but without loss of time—minor accidents:

Character of injury	Accidents causing loss of time	Days lost	Minor accidents
Acid burns	1	3	20
Caustic soda burns.....	—	—	16
Steam and liquid burns.....	4	37	34
Burns from explosion.....	3	1,605	—
Sundry burns	1	13	3
Anilin poisoning	4	15	2
Nitrous fumes	6	21	1
Sundry fumes	5	74	2
Injuries to eye (not mechanical):			
From acids	2	6	15
From caustics and lime.....	2	5	10
Total	28	1,779	103

It is impossible to read these figures and not see the influence of the occupation on even the supposedly nonoccupational diseases as shown in the second table. The workmen who come in contact with the raw material, intermediates, and colors, have a decidedly higher sickness rate than have the workmen not so exposed.

TOXICITY OF COAL TAR DYES

Bachfeld, who has had six years experience as industrial physician to a large German dye works, the one at Offenbach, has recently published the most comprehensive study in the literature of the possible toxic effects of coal tar colors on those who handle them.* He considers only the toxic effect of coal tar colors on the men manufacturing them and discusses two possible effects—diseases of the skin, and inflammation of the eye following the entrance of a foreign particle. During these six years there were 159 cases of skin disease, 32 of them resulting in disability and loss of time. The number of men exposed was 4945. In order to discover whether their occupation had anything to do with the skin lesions, he grouped the employees into those who handled crudes and intermediates; the color makers; the men handling finished colors; and those exposed to neither colors nor intermediates. The proportion of skin lesions was highest in the color makers, with 3 to 4 per cent; next in the department of crudes and intermediates, with 2 to 3 per cent; then the finished colors, less than 1 per cent; and finally, the fourth group, with 0.28 per cent.

Weyl has named ninety-six coal tar colors as poisonous. These belong to the following classes: nitro colors, triphenyl and diphenylmethane colors, acridin, oxazin, and thiobenzyl colors. Twenty-four of these are produced in the Offenbach factory but none has shown itself to be toxic. Only two cases of skin disease could be clearly connected with the handling of colors; one, with sulphur black, and the other, with "Echtmarineblau."

That the finished colors are harmless has been shown repeatedly by practical experience in this factory. Workmen who cannot stand exposure to the crudes and intermediates, who complain of headache and loss of appetite, and are anemic and weak, are transferred to the color department as a routine practice. Indeed, their experience is that the farther the process is from the crude stage, the lower the toxicity of the product. The addition of acid and methyl radicles lessens toxicity greatly. Martius yellow also called Manchester yellow, which is dinitronaphthol, is poisonous, but the calcium or sodium or ammonium salt of dinitronaphtholsulphonic acid is non-toxic. Metanil yellow and Orange 11 are exceptions to this

* Bachfeld, *Zentralbl. f. Gewerbehyg.*, 1920, 8, 113 and 149.

rule, for in spite of the entrance of a sulpho group they are distinctly toxic.

Bachfeld has seen eczema and irritation of the mucous membranes caused by New Blue R. or *Echtmarineblau*. The powder only is irritating, not the solution. Cases of skin disease that arose in the azo color department he attributes to the benzidin and tolidin, rather than to the colors. Seven cases in the fuchsin department were probably due more to the purification agents than to the finished color. The production of methyl violet gave some trouble and in the alizarin department there were six cases of skin disease, but none of them could be traced to the colors themselves. An individual idiosyncrasy had evidently much to do with all of these cases, for a great majority of the workmen remained unaffected by the irritating compounds.

As to the effect on the eye, the question was whether a bit of color dust acted in any way differently from an inert foreign body. It was evident from the records that the department of finished colors had the greatest proportion of eye accidents resulting in disability. Forty-three cases were reported from this department and the colors responsible were triphenylmethane dyes and one oxazin dye. Methyl violet and methyl green were responsible for the greatest number of cases—a fact which is explained by the dust-producing methods in use in this department. There was, however, no evidence that the injury done by the color dust was any greater than that produced by inert foreign bodies in other departments. Bachfeld is unable to explain the unfavorable experience of other physicians, such as Wagenmann writing in Graefe's Handbook of Ophthalmology, unless it be that the workmen, frightened by the strange look of the dye on the eyeball, used such energetic and inappropriate methods to get rid of it as to infect their eyes.

CHAPTER 36

THE RUBBER TRADE

MANUFACTURE OF RUBBER GOODS

THE processes of rubber manufacture are many and varied, and there is a great difference in the extent to which the men and women employed in the different branches are exposed to the danger of poisonous dusts and of poisonous fumes. There are also decided differences in the processes used in different countries. It is impossible, therefore, to make general statements about the dangers in this industry, since what would be true of the manufacture of footwear would not be true of the manufacture of toys and balloons, and a description of the methods used in one factory might not apply to another, although it made the same kind of goods. For instance, nipples for nursing bottles may be made by dipping celluloid forms into a rubber solution and vulcanizing by the vapors of carbon disulphid, both of which are dangerous processes; or they may be made by molding, cementing, and heat vulcanization, processes attended with little or no risk.

The making of rubber is still in an experimental stage and new substances are continually being tried out and adopted or rejected. The description which follows, therefore, is accurate only so far as rubber manufacture in the United States in the year 1923 is concerned. Modifications would have to be made to fit the description to other countries and probably changes will have occurred in the United States before this book comes from the press.

Compounds Used.—In order to make rubber resistant to changes of temperature and to harden it and to make it less adhesive, it must be put through a process known as vulcanization which is essentially the incorporation of sulphur * in rubber, and this may be effected by adding flowers of sulphur to the crude rubber and by subjecting it to dry heat or steam heat with or without pressure, or vulcanization can be effected by means of sulphur monochlorid mixed with some solvent of rubber and used either in liquid or in vapor form. It has been found that heat vulcanization may be greatly accelerated by the addition of certain inorganic and organic compounds, and as many of these have poisonous properties the use of the so-called ac-

* Soft rubber is made with very little sulphur, and the harder the rubber the larger the amount of sulphur used.

celerators adds a very important problem to the hygiene of the rubber industry.

Lead is the most important of the inorganic accelerators, and the only one which is decidedly toxic. It is used chiefly in the form of the oxid, litharge, but one sometimes finds the basic sulphate, known as sublimed white lead, and, very rarely, the basic carbonate. Lead sulphid is black and, therefore, when lead is used in vulcanization a grayish color is given to the product, and this method is not possible for the production of white or vividly colored rubbers. The organic accelerators are beginning to displace lead to a very great extent. Anilin oil was formerly used for this purpose, and when I made an investigation of this industry in 1914 I found great quantities of anilin in rubber compounding, and anilin poisoning was so familiar a sight in Akron that the victims were known as "the blue boys" because of the striking cyanosis of the lips. Now its place has been taken by a large number of other compounds, some of which are closely allied to anilin, others to urea. They do not displace lead entirely in all cases, but lessen very much the amount that is needed. For instance, it is possible by the use of organic accelerators to bring down the litharge in heavy rubber footwear to one-eighth or one-tenth of what was formerly used. It is also possible to vulcanize at a much lower temperature, and certain goods which would be injured by high temperatures can be vulcanized by heat if an organic accelerator be added. Thus, ordinary heat vulcanization would destroy the leather in the mixture of ground leather and rubber which is used to make soles for shoes. Another important use for organic accelerators is in vulcanizing synthetic rubber which is abnormally slow in its reaction with sulphur.

In 1918 the Rubber Section of the American Chemical Society appointed a committee with Richard D. Earle as chairman, to investigate the harmful effects, if any, of the newer organic accelerators which had been coming into use recently. (1) The committee considered the following five compounds: anilin, hexamethylenetetramin, para-phenyldiamin, para-nitroso-dimethyl-anilin, and thiocarbanilid. They found the last to be much the least harmful, for it decomposes forming phenyl mustard oil which seems to cause only slight cyanosis. Anilin is of course the cause of more or less marked cyanosis, and hexamethylenetetramin and para-nitroso-dimethyl-anilin have a distinctly irritating effect on the skin producing erythema or vesicular eruptions. (See page 434.) The most poisonous of all, and probably the most dangerous of the substances used in rubber compounding, is para-phenyldiamin. For the physiological effects of this drug, see page 508.

According to Bedford and Scott (2), the most powerful organic accelerators known today are the carbon disulphid reaction products of strong organic bases, the most widely used of which is thiocar-

banilid also called diphenylthiourea. When this compound is heated to the temperature commonly used in the vulcanization of rubber, hydrogen sulphid is formed. Both hydrogen sulphid and carbon disulphid are formed when formaldehyd-anilin is used and the same thing is true of hexamethylentetramin, which is said to produce at vulcanizing temperature (130° to 150° C.) large quantities of hydrogen sulphid, carbon disulphid and ammonia.

In addition to these toxic gases which are formed and which may escape when the vulcanized goods are taken out, phenylene mustard gas may also be evolved. A special complaint was made of this gas in one large factory where the men on the vulcanizers and on the hydraulic presses for heels and soles complained that it made their eyes sting and water. Anilin fumes are said to be formed by the decomposition of diphenylthiourea.

It may be well to summarize briefly the processes of rubber manufacture which involve the use of these different compounds. Molded goods and mechanical rubber, automobile tires and footwear are heat-cured, usually with an organic accelerator and more or less litharge. Druggists' supplies may be made in the same way, except white and bright red-brown articles, for which zinc white or the golden sulphids of antimony are used. Druggists' supplies may also be made by dipping, in which case no lead or organic accelerator is used. The dangers in this method consist of the use of large quantities of naphtha or benzene to make the rubber solution, and of the use of carbon disulphid for vulcanization. Rubber clothing may be heat-cured and compounded with lead and organic accelerators, or without lead, or it may be made on a spreading machine and vapor cured. Finally, hard rubber contains little or no lead, does not need cement and is always heat cured. The dangers involved in the use of rubber cement and of rubber solution for dipping and of rubber paste for spreading depend on the solvent which is used. If petroleum solvents are used the risk is far less than if coal-tar benzene is substituted.

PROCESSES USED IN THE MAKING OF RUBBER GOODS

Compounding.—Measuring and weighing the chemicals which are to be added to the crude rubber is the first department which is of interest to the industrial physician. Here the litharge is handled, sometimes sifted or bolted, sometimes used directly from the keg, sometimes dumped into big storage bins. There is rarely any evidence of special care in the handling of the litharge, and as a usual thing the workmen have no idea that there is any need of care. Several times I have been told by foremen in compounding rooms that they did not use any lead, and when I pointed to the litharge they were surprised and said they had never thought that litharge

was lead. The men employed in these rooms weigh out the different compounds into batches which are sent down to the mixing mills. The rooms are often thick with dust, the men's overalls covered with powder, and no effort made to keep the dust from spreading beyond the confines of the compounding room. The fact that a rubber factory is well built and that the management shows unusual interest in the welfare of the men does not mean that the compounding room will be found clean and well cared for, or even that washing facilities will be provided for these men. Often the contrary is true, and the men engaged in the very sort of work that makes personal cleanliness most important may be given no proper provision for it. The organic accelerators are handled here also and the men in the compounding room share with the men in the mixing mills the irritating effect on the skin of these compounds. If anilin is used, and apparently, judging from an article by Davis (3) of Akron in 1921, it is still used in some factories, the compounders are exposed to both fumes and contact unless great care is taken.

Mixing.—The crude rubber, together with the chemicals which are to be mixed with it, is carried in an open pan to the mill room and given to the men at the mixing mills. The mill man lifts the pan with the mixture and empties it at about the level of his head into the open mill, striking the pan repeatedly against the mill to get the last of the powder. The rubber and the powder are caught and carried between two revolving heated cylinders and as they turn much of the powder falls and is caught in a pan below. The workman stoops down and with a long handled brush sweeps it up, scoops it with a shovel, and throws it back on the rubber. Every few minutes he cuts the rubber which comes out between the cylinders and throws it back into the mill till the powder is thoroughly incorporated. At the beginning and whenever the powder is swept up from the pan and thrown back and the sheet of rubber cut off and dropped back a great deal of dust rises and spreads out into the room. One man may mix as much as fifty batches of rubber a day. Even the provision of an "apron" to catch the powder or hoods with exhausts to carry off the dust have never in my experience been entirely efficient, and most of them are quite useless. If anilin is used it may be added first to crude rubber and mixed in what is called a "warm up mill" and the mixture then taken to the mixing mill where the other compounds are added.

Many factories have hoods over the mills but some make no attempt to carry off the dust, and in those in which hoods are provided the construction of the hood and the strength of the exhaust are rarely efficient for the task for which they are designed. Work on these mills is dangerous according to the character of the compounds used. If litharge is one of the compounds, lead poisoning is very likely to occur. Three of the cases of severe lead encephal-

opathy described in chapter 6 were caused by work on the mixing mills. Sharpe (4) of Toronto, reported in 1923 that in a rubber factory where 25 men were employed in contact with lead there were in one year four cases of plumbism in the compounding room and seven in the mixing room. My investigation in 1914 disclosed 66 cases of lead poisoning in rubber works during 1914, distributed among the various branches of the trade as follows: tires 27, footwear 9, clothing 6, druggists' supplies 3, mechanical rubber one, factories making all kinds of goods 20. The men were all working in compounding or mixing. The greater number had been employed more than a year, but one compounder had worked only three months, another nine months, and a third eleven months, before being taken ill.

It must not be forgotten that if the mixing mills are placed, as they often are, in close proximity to other processes, the danger of lead poisoning will not be confined to the men on the mills; for the dust will scatter and contaminate the air of the rest of the room. Cases of lead poisoning have come to my attention among rubber workers who were not mill men but whose jobs were in the room with the mills.

Buffing and Grinding.—The only other department in which there may be any danger of lead poisoning after mixing is over is in roughening the surface of rubber and in grinding up old rubber for shoddy. A good deal of rubber dust is produced by some kinds of buffing in tire building but it is not light or dry, it tends to stick together or fall to the floor, although in very neglected factories it may have a chance to dry and blow about. A sample of such dust was submitted to the Bureau of Standards in Washington for the determination of the presence of soluble lead as determined by the "Thorpe test" and a small quantity, 0.74 per cent, was found.

Much more dust is formed when old rubber is ground up in rubber reclaiming, and the dust is sometimes much richer in lead. A sample tested by the Bureau of Standards yielded 6.45 per cent of soluble lead.

The trouble caused by the use of organic accelerators is not confined to the compounders and mixers, but affects also the men handling compound rubber in many processes. Kratz ^{*}(5) states that in the manufacture of tires and inner tubes dermatitis is very common, not only among the men on the mills but among those who work on the calenders and among the men employed in cutting inner tube stock, splicing inner tubes, cutting tire stock, and building tires. There is always more "rubber rash" in hot weather, partly because the skin is more exposed then, partly because free perspiration favors it. The mill men warm up stock for the calenders on

* See page 434.

the mills, then cut it off and carry it on their bare arms or shoulders to the calenders. The men on the calenders grasp the roll with the bare arms and carry the roll of stock on their arms and against the shoulder and neck. Probably urotropin, hexamethylenetetramin, is more irritating to the skin than any of the other organic accelerators, but anilin has this effect to a certain degree, and anilin-formaldehyd still more. Phenylenediamin would probably come next to urotropin.

Cement.—The solvents used in the rubber industry are all volatile poisons. Petroleum naphtha and benzin are used most commonly, then coal-tar benzene (benzol), and, to a lesser extent, carbon tetrachlorid, carbon disulphid, and trichlorethylene. Rubber cement is made with one or more of these solvents, the work being carried on in a separate room or a separate building and with great precautions against the escape of fumes because of the fire risk. There is little trouble from poisoning among the cement men, partly for this reason and partly because they are only obliged to enter the room from time to time.

The filling of small cans of cement for the trade is attended with more escape of fumes, and such cement is very likely to contain benzene and carbon disulphid. The work is done by hand and requires no skill, so young lads are often found doing it. The solutions of rubber for making dipped rubber goods and the rubber "dough" used on spreading machines are made in the same way as rubber cement. Benzene is now being substituted for naphtha in many of these rubber solutions, especially in making automobile tires, and pure benzene may be used for swabbing in tire building, and for dipping cord tire fabric. Benzene cement is often used in cementing tire carcasses by hand, and in fastening leather and rubber together, and in spreading cement on tire beads.

Dipping.—The largest quantities of rubber solution are used in the making of dipped goods. Seamless rubber gloves, seamless druggists' supplies, nipples for nursing bottles, finger cots, toys, face masks, plain bathing caps, and balloons are made by dipping celluloid or wooden forms in a solution of rubber in benzin. The forms are allowed to dry a little and are then dipped again and again until a thick enough layer of rubber has been formed, when they are thoroughly dried and vulcanized. Naphtha is the solvent used for ordinary goods, but benzene is used for surgeons' gloves.

The process requires a heat of 80° or 90° or even 98° F. in the dipping room and the evaporation of the dipped goods fills the room with fumes. Because the temperature must be maintained windows cannot be opened, artificial ventilation is necessary, and fumes, since they are heavier than air, must be removed by down-suction. The tank is opened every time a form is dipped and each time it is left uncovered from 7 to 10 minutes. About ten tanks can be

managed by one man who moves from one to the other leaving the drying forms behind him. Unless the ventilation is properly controlled, the air in a dipping room becomes heavily contaminated with fumes.

Spreading.—This is one method of making water-proof goods, that is of covering a strip of cloth with a layer of rubber. It is not as usual in the United States as is calendering, which means passing the fabric and a very thin rubber sheeting between heated rolls which press the rubber into the cloth. This is a very much safer method. In spreading, a solution of rubber in naphtha or benzene is used, making a rather thick paste. It is customary in this country to put the fabric first through a frictioning machine which rubs in the paste till the cloth is thoroughly impregnated and then less spreading is needed.

A spreading machine consists of a table with heated rolls over which a spreading knife is suspended in such a way that it almost touches the first roll. The fabric passes under this knife, and as the workman places against it a portion of the rubber dough the knife spreads it over and presses it into the cloth which then passes on along the spreading table over steam-heated pipes in order to evaporate the solvent. Unless the whole table is enclosed and a strong suction provided, the fumes of the solvent will be driven into the room. Fortunately the fire risk is great enough to require a fair degree of ventilation, but I have never been in a spreading room in which the ventilation provided was entirely adequate.

Cementing Seams.—Smaller quantities of rubber solution are used as cement to join together the seams of rubber footwear, raincoats, hot-water bags, toys, tubing, the different layers of tires, and a multitude of other articles. Cement may be made with either naphtha or benzene and rarely contains some carbon disulphid. It is sometimes as thin as a thin soup, or it may be thick enough to handle with a trowel. It is carried from the churning room in large cans, usually, but not always, covered, and the foreman pours or scoops out portions of it into tin cups or small cans for the use of the cementers. This may be done neatly and the cans carefully covered afterwards, or there may be a great deal of spilling over the floor, and the cans may be left open all the time. On the table beside each worker is a cup with cement and usually one with the solvent as well; for edges can be made to adhere by means of pure naphtha or benzene, and in making rubber tubing and inner-tubes one of these liquids is sometimes used in place of cement. The cups used by the women hold about half a pint, those used by the men in cementing clothing and tires may hold a quart or more. In one raincoat factory the men use large shallow open pans of cement about twelve inches in diameter. There may be two hundred men and women working with cement in one large room of a footwear

or clothing factory, but the air is not often seriously contaminated or oppressive. There is, however, an unnecessary escape of fumes in some plants, because the supply cans are left uncovered. It is impossible to prevent the evaporation of the solvent from the cement that has been smeared on the goods, but it is perfectly possible to put on the cement cans lids of such a character as to allow the brush to pass through. Recently machines for the application of cement have been introduced. I have seen one for cementing inner soles of shoes and another for making rubber-coated thread for cord tires.

Other departments in which naphtha or benzene fumes may be encountered are: in making very light rubber shoes, called zephyrs, by dipping a cloth shoe in a solution of rubber, drying it, and then cementing on a rubber sole; in printing rubber cloth with colors mixed with naphtha or benzene; and in varnishing rubber boots and shoes by dipping them in large open tanks containing a naphtha varnish.

Vulcanizing.—The possible escape of poisonous gases after heat vulcanization has already been mentioned, but this danger is slight and heat vulcanization is much the safest way of curing rubber. Curing by the Parkes' process involves exposure to carbon disulphid or, rarely, to benzene or carbon tetrachlorid. This may be done in one of three ways: by subjecting the goods to vapors of carbon disulphid, by dipping them in the liquid, and by painting the liquid on the goods with a brush.

In general it may be said that Parkes' process is always used for vulcanizing toy balloons, finger cots, and colored bathing caps. Both heat and "acid" curing, as Parke's process is called, may be used for rubber clothing, gloves, toys, balls, nipples, rubber sheeting, and rubber dam. Heat curing is always used for tires, molded goods, mechanical rubber, medical supplies, except gloves, footwear, and hard rubber. The inner tubes of tires may be cured by either method. As a usual thing the surface of the two ends of the inner tubes is roughened, then painted with a mixture containing sulphur monochlorid and then joined, so that splicing and vulcanization are simultaneous, but heat curing is also used in some factories for inner tubes.

The tendency in this country is to abandon the acid cure and to use heat vulcanization even for rubber dam and colored goods. It is said by many American chemists that carbon disulphid vulcanization is uncertain and unreliable, especially in a climate with such extremes of temperature as ours.

I have seen all three methods of acid cure in use in American factories, but the vapor cure, only in seven. In vapor curing the objects to be vulcanized are spread out or hung up in a chamber which is warmed by coils of steam pipes. Shallow receptacles filled

with pure sulphur monochlorid or with benzene as a diluent, or with carbon disulphid, are placed on the floor of the warm chamber which is then closed, and the vapor, the evolution of which is hastened by the heat, is allowed to act on the rubber. At the completion of the process the further action of the sulphur monochlorid is stopped by driving in steam or vapors of ammonia or sometimes simply by opening up and airing. The risk in this work depends on the solution used (pure sulphur monochlorid is harmless) and on the method of getting rid of the fumes before the men go in to remove the cured goods. Vapor curing is the cheapest method of vulcanization, both in labor and in the equipment required, but it can be used only for the very thinnest goods such as surgeons' gloves, rubber dam, bathing caps, finger cots, babies' bibs, barbers' aprons, and the poorer grades of clothing.

For vulcanization by dipping, carbon disulphid is almost always the solvent used and there is a great deal more used in this process than in vapor curing, and the fumes are more likely to do harm, because, coming from open tanks and from drying goods, they are more widely diffused. If simple precautions be taken in vapor curing nobody need be exposed to fumes, but in dipping it is impossible to escape them unless the process is carried on mechanically under cover. In 9 out of 35 rubber factories I found goods cured by dipping in tanks which, with one exception, contained carbon disulphid as the only solvent. In one, the vehicle was equal parts of carbon tetrachlorid and disulphid. According to Pearson, (6) the mixture used in American factories is usually one part of sulphur monochlorid to 30 or 40 carbon disulphid, but for balls and balloons the proportion of the latter may be even higher.

The vapors of carbon disulphid escape not only from the tank but from the dipped goods which are put on racks and set aside to dry. The only efficient way of getting rid of these fumes is by a down suction through vents in the floor, but even then the workmen are not protected entirely, and in some plants the fumes are even allowed to escape and to contaminate the air of neighboring rooms. In only one factory did I find a very dangerous method in use which is described in British publications. This is a method of vulcanizing rubber cloth on a machine similar to a spreading machine, the cloth dipping into a long trough filled with carbon disulphid and sulphur monochlorid and passing over rolls, then being taken off and hung up to dry.

The third method of cold cure consists of painting the mixture of sulphur monochlorid over surfaces that are to be vulcanized, and it is used in splicing inner tubes of tires and in making hoof pads for horseshoes. Because of the great fire risk when carbon disulphid is used, some factories have substituted carbon tetrachlorid; others use benzene either alone or with a small amount of carbon disulphid.

The exposure to fumes is not very great in any case, and as a usual thing an exhaust with a down draft is placed directly in front of the workman who holds the end of the tire over it so that the drip from his brush as well as the fumes are caught. German authorities consider the work dangerous enough to require that it be done under a glass cabinet furnished with an air exhaust.

Processes in Reclaiming Rubber.—The essential features consist of grinding and washing old rubber, getting rid of the textiles by the the action of acids or alkalis, and softening the rubber, compounding and vulcanizing. A new British process is designed to dissolve out the rubber from the fabric to save the latter.

In the first process the rubber is ground usually with the production of a great deal of dust, especially if hard rubber is used, then put through warm rolls which melt it to a sticky mass. This goes into a digester where it is treated, usually with alkalis, sometimes with dilute acids, to rot the shreds of cloth which are mixed through it. The rotting fluid is washed out, the rubber dried, and compounds of various kinds added to it. These compounds include lead, usually litharge, crude phenol, phenol-formaldehyd condensation products, cresol, gasoline, kerosene, turpentine, anilin, toluidin. From this point on, the processes are the same as for crude rubber manufacture.

In the second process the old rubber is ground coarsely, placed in a rotating drum furnished with a stirring device, and filled with benzene, toluene, xylene or ether, or mixtures of these. After vigorous churning the rubber solution is removed, fresh solvent is added, and more dissolved rubber is removed. The fabric saturated with these solvents is dried by blowing hot gas through it, and the gas passes through a condenser where the solvent is partly recovered. The solution tank is kept at about 115 degrees C.

The dangers in rubber reclaiming come from lead-laden dust and from the volatilization of solvents and of organic accelerators. The second process involves much more risk than the first.

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CHAPTER 37

TURPENTINE AND TOBACCO

TURPENTINE

OIL of turpentine is a volatile oil distilled from oleoresins from pines, usually composed of more or less oxidized products of various terpenes. All terpenes have the formula $C_{10}H_{16}$ and turpentine oil is a mixture of them (1).

Ramazzini spoke of turpentine as an industrial poison, in the 18th century. It is locally irritant to mucous membranes and to the skin, and when absorbed it has an exciting effect on the central nervous system. The vapors are toxic and it is possible that absorption takes place also through the skin, although animal experiments to prove this have not succeeded. Lehmann (2) painted the skin of a dog daily for 11 months with no result except a thickening of the skin. He tested the vapors on several species of animals. Dogs showed no symptoms till the amount reached 4.5 mg. per liter of air when mild signs of irritation appeared which increased to decided discomfort at 6.0 mg. per liter. Cats were more sensitive, experiencing discomfort at 1.17 mg., and at 4.0 to 6.0 mg. they cried out, staggered, lost consciousness and recovered with partial paralysis.

The nervous symptoms were very marked in these animals and Lehmann remarks that a poison which produces a conspicuous effect on animals at 4-6 mg. per liter of air has probably caused subjective symptoms, headache, etc., at a lower point than that.

In industry, turpentine poisoning occurs chiefly if not wholly through inhalation of vapors. There is a sensation of burning in eyes and throat, cough and hoarseness, a sense of tightness in the chest, breathing is rapid, then there is headache, dizziness, palpitation of the heart. Some men complain of salivation, running nose and running eyes, and sore throat, and there may even be an attack of bronchitis. In a few hours the urine that is voided has the odor peculiar to turpentine poisoning, familiar to painters and varnishers and usually likened to the odor of violets. It is due to the presence of conjugated glycuronic acids.

In severe cases, which occur when men are using a paint rich in turpentine in small airless places, such as the cabins of ships, there may be mental confusion, an effect like that of alcoholic intoxication, dizziness which may make the man fall from a ladder or scaffold,

and which instead of improving when he reaches the open air may increase, so that he falls to the ground (3). More or less strangury is likely to follow and the urine may be dark in color. The irritating effect on the skin, which is the basis for the therapeutic use of turpentine stupes, is shown in erythema, urticaria, etc. E. Schafer of the German Factory Inspection Service reported a fatal case of industrial poisoning from turpentine vapors (4).

In chronic turpentine poisoning symptoms referable to bladder and kidneys are sometimes conspicuous. There is frequent micturition, often difficult or even painful, and the urine may show evidence of degeneration of the kidney epithelium. A young woman of 22 years who was treated in the Occupational Disease Clinic of the Massachusetts General Hospital, complained of weakness and fatigue, of attacks of vertigo and once of vomiting, but her chief complaint was that she was obliged to pass urine very frequently, sometimes every hour during the day. The urine was whitish and had a curious odor. Her work was to dip hot shoe polish, containing turpentine, from a kettle and pour it into small containers.

In the report of the Commission on Occupational Diseases of the State of Illinois made in 1911, there is a section on turpentine poisoning. Hayhurst, Flynn and Nicholls examined 62 painters and varnishers in Chicago, older workmen chiefly, who had been employed in interior work, ruling out so far as possible all cases of plumbism.* The men were between the ages of 24 and 64 years and all but 15 had worked more than 10 years. Most of the 62 stated that they had suffered more or less frequently from drowsiness, headache, nausea, loss of appetite and even vomiting and dizziness while working with turpentine. Fifty-four had had bladder trouble at times, 18 of them having been under medical treatment for kidney and bladder trouble. Twenty-one had had inflammation of the eyes, fourteen complained of irritation of the throat and bronchitis, and seven had had skin eruptions. Analysis of the urine was made of 44 men and 14 or 31.8 per cent proved to have organic kidney disease.

Chronic turpentine poisoning is probably fairly frequent among painters and varnishers, but it is usually hard to make sure of this, now that the expense of this volatile thinner and drier has led to the adoption of cheap substitutes, chiefly naphtha, or "petroleum ether." These, though not so toxic as turpentine, are more volatile, and painters often complain more of the effect of quick-drying paints than of the older turpentine paints. Since they work now with one thinner and now with another it is impossible to be quite sure which is responsible for the illness which results. Thus Albaugh reported at the Cincinnati meeting of the American Public

* For an account of the controversy over the relative importance of plumbism and turpentine poisoning in painters, see Chapter 14.

Health Association in 1915 the case of a lad of 18 who died from the effects of volatile liquids in the varnish which he had applied through a spray-gun, during a period of 8 months. He had anemia, the red count was 3,000,000 (white not given), constipation, gastric pains, low blood pressure, temperature 94° F., his body was covered with purpuric spots and his urine contained casts and albumin. He died in delirium on the fifth day after the physician first saw him. The varnish contained not only turpentine but naphtha and benzene and it is the last-named that one would choose as the poison responsible for his purpura, yet Mayer (5) saw a case of "purpura fulminans" in a child poisoned with turpentine.

Porrini (6) examined 234 Italian painters and varnishers who used all three of these thinners but he believed that he could distinguish the symptoms of turpentine from those caused by benzin, and coal-tar benzene. These men were house and ship painters. He found that 27 of the 89 house painters and 106 of 145 ship painters suffered from mild or severe turpentine poisoning as evidenced by irritation of the conjunctiva, throat, larynx and nose, and by headache. In some, these symptoms were much exacerbated and in addition there was dizziness and mental confusion. Alcoholism and summer heat increased the trouble and the painting of small cabins was the worst work.

Harris (7) examined a large group of painters in New York City, 402, all in interior house decoration. He says that painters seldom consult a physician when they suffer from the effects of turpentine, benzin or other volatile thinners, but accept these symptoms as part of the day's work. For this reason it is hard to learn anything accurate as to the frequency of intoxication from these vapors or even to be sure which one was in use when the illness developed. Harris was obliged to class together all the thinners and driers, petroleum distillates, benzene, turpentine, methyl alcohol, acetone, etc. He found that at least 70 per cent of all those examined gave a fairly clear and recognizable history of one or many attacks of illness connected with some volatile substance in paint or varnish and 142 had a history of recent severe intoxication in which some or all of these symptoms were present: a sudden sense of weakness in the legs, irritation of the eyes, difficult breathing, and dryness and irritation of the throat, cough, headache and dizziness, sometimes bad enough to cause a fall from scaffold or ladder. In addition, there was often nausea, vomiting, painful and frequent micturition during the day, sometimes bloody urine and once bloody diarrhea. The urine was often dark with a peculiar odor.

With the increasing expense of turpentine oil a large series of substitutes have come into use, and many complaints are registered on the part of workmen who use these substitutes. Thus an indus-

trial insurance company reports to me that there is much difficulty connected with the use of a paint containing turpentine derived from the stumps and roots of pine trees by destructive distillation, although gum turpentine does not give any trouble. It is of course highly probable that the destructive distillation of wood results in a mixture of toxic substances of which turpentine is only one and perhaps not the most dangerous.

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TOBACCO

The general impression that tobacco dust is toxic to the workers in tobacco factories is not borne out by actual investigation of the physical condition of these workers. Thus Oliver (1) comments on the assertion made by Galezowski and later by de Schweinitz in the United States, that a partial or total loss of eyesight sometimes occurs as a result of exposure to tobacco dust in industry. Oliver says that Shears found not one case of defective sight among 1200 men and women in British tobacco factories. He himself visited the French factory in Pantin-Aubervilliers, and could hear of no visual defects there.

In 1909 Dowling (2) of Cincinnati described his visit to the large tobacco factories situated at Issy near Paris which employ 1200 persons, 1000 of them women. This factory being under government control, for tobacco is a government monopoly in France, employs no minors and is very well managed. Smoking is against the rules, and Frenchmen do not chew tobacco. The medical director told Dowling that the occurrence of tobacco blindness was very rare. On the other hand, out of something like 3000 employees in the tobacco factories of Cincinnati, whom Dowling examined during a period of ten years, more or less reduction of the visual power, together with a confounding of colors for central vision, was noticed in about five per cent of the men. This, however, is not industrial poisoning, for the women who do not smoke are quite exempt. The air of the factory does not irritate the eyes or produce a general toxic effect on the employees. Only those that smoke excessively are affected.

There is also a general impression that tobacco dust is harmful

to the lungs, but here too detailed studies fail to reveal any increased incidence of tuberculosis among cigarmakers. In the German factory inspection report for 1921 the Dresden office discusses the effect of tobacco dust on the workers. There is a very general irritation of the throat and mouth which is purely mechanical and shows itself in a feeling of thirst and in inclination to cough, but many become accustomed to the irritant and later suffer no discomfort. The nicotin does not seem to exert any effect. Palitzsch (3), also of Germany, published recently a clinical report of a case of chronic pulmonary disease the exciting cause of which he believed to be continued breathing of fine tobacco dust from a machine for grinding cigarette filling. The diagnosis of pneumokoniosis was based on the X-ray findings, the negative findings for tuberculosis, and the long and favorable course.

In 1921 the Swedish National Anti-Tuberculosis Society (4) carried out a systematic medical examination of employees in tobacco factories, ten specialists being employed to make the examinations. Isolated investigations had already been carried out in 1899 and in 1905, the results of which seemed to show that employees in tobacco factories came next to printers and bookbinders in their tuberculosis rate. It was found possible to persuade from 84 to 98 per cent of the employees to submit to examination. They were careful to divide the workmen actually handling tobacco, from those engaged in other work such as box makers, pasters, and machine operators, and a division was made between those working in the open air and those working in factories. The conclusion arrived at was entirely negative, the report declaring that it is incorrect to state that employees in tobacco factories are more affected by tuberculosis than are workmen in other trades. The report also includes the results of similar investigations undertaken in other countries, such as Austria, Finland, England, France and America, all of which arrived at approximately the same conclusion.

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CHAPTER 38

THE PREVENTION OF INDUSTRIAL POISONING

It is not my intention to describe in detail the practical measure by which a factory or workshop may be rendered safe from toxic dust and vapors. That is the task of the engineer, not of the physician. All that the latter can do is to make clear the principles on which methods of protection must be based and then leave their actual execution to the experts in the mechanical trades. These principles depend on the character of the poisonous compound in question, above all on its special mode of entrance into the human body. If this is by way of the inspired air, the prevention of fumes and dust becomes the matter of first importance. Whatever money is available for factory hygiene must be expended first on mechanisms to prevent poisoning the air, even if this means a scanty equipment for the washrooms and lunchrooms.

The physician will sometimes be told that certain processes cannot be carried on without contamination of the air, that the workman must be protected in some other way, by some sort of respirator or mask. This brings him into a field of controversy in which difficulties await him. The experiments now being carried on by the United States Bureau of Mines will doubtless throw much light on the question of the efficacy of such devices against different sorts of dusts and vapors, but at present it does not seem safe to say more than this: no apparatus, respirator or army mask, through which a man can breathe with entire ease and comfort while doing heavy work, will serve to hold back all the poisonous dust or vapor in the air. If such a mask is really efficient it will cause some discomfort and difficulty to the wearer. This means that it is a device for emergency use, not for use during eight or ten hours continuously, day in and day out, for the best shop discipline would break down under a strain like that, and the foreman would have to pretend not to see the masks worn on the forehead or around the neck, if he did not wish to lose most of his men.

A mask, carefully selected for the particular poison against which protection is needed, should be provided for emergency use, during short periods only, in all places where there is danger of fumes or dust, but to place one's trust in masks for the continual protection of men is simply to close one's eyes to unpleasant facts.

If the poison belongs to those that gain entrance primarily through

the skin, cleanliness of the premises, of work-benches and apparatus, is essential and in addition it is necessary to furnish clean working clothes and facilities for bathing, as well as for the usual washing of hands and face. This is already accepted as a necessity in connection with the compounds which produce trade eruptions but it is quite as essential for those which produce systemic symptoms without local irritation. If direct contact with the poison cannot be avoided, then every means must be adopted to protect the skin. As much of it as possible should be covered with clean underwear, overalls, socks, and caps, and the surface which is necessarily exposed may be covered with a bland ointment or dusted with powder or washed frequently. It must be remembered, however, that there is a risk in too much washing of the human skin and that care must be taken in such cases to use the least irritating cleansers, to avoid scrubbing, and to restore the lost oils of the skin by inunction with some animal fat.

The consensus of opinion among men experienced in such industries as the production of coal-tar intermediates, where skin absorption is of prime importance, seems to be against gloves as a protection. Gloves make the hands sweat and the skin soft and hot and in excellent condition for the absorption of poisons, and if there is even a small rip or tear in the glove letting the dust or liquid in, it will form what is practically a poultice of poison around the hand.

As has been shown in the preceeding chapters, there are poisonous dusts which not only contaminate the air but also produce poisoning through the intestinal tract if the worker has his hands and face covered with such dust when he handles his food or his plug of tobacco. The protective measures indicated in such cases, provision of a separate lunchroom, only to be entered after thorough ablutions, are too well known to need anything more than a mention.

The factors that favor absorption of industrial poisons, or that heighten their effect, were dealt with in the first chapter. These also come within the field of the physician. Heat from furnaces, steam from tubs and tanks, may seem to be outside his province; long hours and low wages, the employment of young lads and girls, may seem to him questions for the management alone, but the incidence of sickness among his charges is profoundly affected by such factors as these. He should not fail to assume some responsibility for the feeding of the employees at least so far as the noon-day meal is concerned, for if a warm, wholesome lunch is furnished them it will go far to protect them against poisoning.

The industrial physician is entrusted with the ungrateful task of selecting by physical examination, men and women whom he considers fit to face the risks of work in poisonous occupations. The textbooks warn him to reject the tuberculous, the anemic, the individual with lesions of the kidneys or heart, and this is doubtless

wise, but he is an innocent optimist who believes that after all this is done he has guarded himself against distressing accidents. The management may believe that such a weeding out has rid the force of the over-susceptibilities; the wise physician knows that this is not true and that the most vigorous and blooming men and women may be the ones to develop lead encephalopathy (see Tanquerel, page 5) or benzene purpura hemorrhagica (See Meda, page 471) and that the only way to guard against this is to keep constantly on the watch for the warning signs and then to remove the victim before serious harm has been done.

To do this, it is best to make a careful classification of the different jobs in the plant, according to the degree of danger in each, and to devote special attention to the employees in the class that heads the list. New hands who are given jobs in this class should be examined at frequent intervals till the physician is able to say whether they have a normal degree of resistance to the poison in question, for if not, it is only good economy to shift them at once to other work. It will always, however, be necessary to subject all the employees in the dangerous class to routine examination, for at any time some disturbance of metabolism may break down the defenses of one who was apparently immune.

The physician should be the one to whom the education of the employees in personal prophylaxis should be entrusted, or at least he should plan and supervise it, though it may be he will not have enough of factory vernacular to "get it across." But he should insist on the necessity of such instruction. The idea is often held by employers who are using unfamiliar poisons that it is best to say nothing about them for fear of frightening the men away. This attitude on the part of the men in charge of munition works during the war was a distressing obstacle in the way of all who tried to introduce into American plants the safeguards successfully worked out in the British, which could not be done if the fiction were maintained that trinitrotoluene might indeed explode, but was otherwise quite harmless. As a matter of fact we all knew the workmen were not hoodwinked, they were only muddled. They knew perfectly well that something was there that made men ill but just what it was and how it affected them they did not know, so they ended by suspecting everything and promptly quitting the job if they fell ill, regardless of whether the illness were caused by the poison or not. The plants which were under intelligent management, with careful instruction of the men and prompt resort to the dispensary even for slight ailments, had a much lower labor turnover than those which followed the policy of secrecy.

The task of education is not easy—it is exhaustive of time and temper alike, but it is a duty which cannot be shirked, especially in unorganized industries. Trade Unionists are to a varying extent

responsible for the conditions under which they work, but the great majority of the poisonous industries are unorganized. Much of the dangerous work is done by foreign-born men and women and toward these workers the responsibility of the management and of the physician is far greater. Such people are like children in their readiness to accept the conditions of life, they will work long hours, in heat and filth and poisonous dust, they make no demands for security or comforts, they are quite free from the irritating interference of trade union officials. These are great advantages to the employer but if he accepts them he must accept the accompanying disadvantages. With child-like docility goes childish ignorance, recklessness and obstinacy. The management cannot throw upon such men and women the responsibility for their own health and safety. They are not capable of assuming it. For them the protection must be especially elaborate, it must be "fool-proof," the vigilance of the physician must be unrelaxed.

It may happen that the physician will be asked what to do in a department where all known mechanical devices for the prevention of poisonous dusts and vapors have been applied, and yet, because of the very nature of the process, there is still contamination of the air. In such cases there seem to be but two courses open. The dose of poison may be reduced by shortening the exposure, cutting it down perhaps to only a couple of hours in the day's shift or even less than that. Or the work may be allowed to go on under the watchful eye of the physician who knows that a certain warning symptom will appear in time for him to order a change of work before real harm has been done. An excellent example of such a system is described in the chapter on tetrachlorethane. With newer poisons, it may be that the physician will have to study for himself the physiological effects in order to discover what sign or symptom can be depended on to give the needed warning of danger.

In closing, let me beg the industrial physician not to let the atmosphere of the factory befog his view of his special problem. His duty is to the producer, not to the product. If measures which he knows to be necessary are declared impossible, because they interfere with production, he may have to yield, but let it be understood that such yielding is against his judgment. A sanitary engineer may be told by a city council that it cannot afford a pure water supply and he may have no choice but to accept the verdict. But he would be greatly at fault if he allowed the city fathers to believe that the half-way measures they plan will safeguard the community against typhoid fever. In the same way the industrial physician may be obliged to abandon his plans for protecting his charges against poisoning because the expense is greater than the management will allow or because a change in the method might make the product less perfect. But in so yielding let him be careful never to sacrifice

his own intellectual integrity nor adopt the standards of the non-medical man to whom the proper working of the plant is of first importance. His task is to safeguard the health of the patients who are entrusted to him, often without any volition of their own. The successful production of goods is outside his field. To the physician, always, life is more than meat and the body than raiment.

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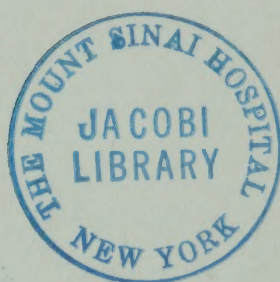
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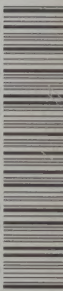
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